Vegetable Production and Marketing

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Hints for the Use of This Book

Attainment of the objectives stated in the Preface calls for well-planned study and the utilization of many resources.

Use of literature. Since this text is condensed, and since many situations call for fuller treatment of some subjects, bulletins, periodicals, and other publications, both those of general scope and those that have been written to fit the needs of various states and regions, should be consulted freely. Especially does this apply to matters of soil fertility, insects, and diseases, in respect to which recommendations are necessarily localized and subject to constant change.

The reference lists have been designed primarily as guides for further study. The teacher should know far more than he tells his class, and the student should be encouraged to delve further into topics that are of special interest to him or pertinent for a specific crop or area. Library or term papers afford opportunity to arouse curiosity, to encourage independent study, and to develop skill in finding out what has been learned about a given topic.

Though the reference lists are far from complete, the bibliographies in publications cited will lead to other sources of information, including many older papers that are not to be neglected because a decade or two has passed.

Teachers and students should learn to consult current reference works such as the *Wilson Index of Periodical Literature*, *Biological Abstracts* and *USDA Bibliography of Agriculture*.

Frequent reference should be made to elementary books on botany, chemistry, and physics, and no less to more specialized works on soils, fertilizers, plant physiology, genetics, diseases, insects, and other subjects. A large dictionary affords succinct information on scientific terms such as respiration, gamete, calorie, and glucoside. Few current statistics are given in this book;

for such information the reader should consult *Agricultural Statistics* of the United States Department of Agriculture as well as various printed and mimeographed crop and market reports. A good library including these materials should be frequently and faithfully used by both teacher and student.

Laboratory exercises afford an opportunity to relate principles to practice, to raise questions and to find answers, and to demonstrate the effects of treatments and procedures, as well as to establish skills and to teach good workmanship. Teachers will find little difficulty in planning exercises dealing with the characteristics of seeds and plants, soils, and materials, with the growing of early plants and the culture of crops, or with the harvesting and marketing of products. Trips and surveys are most valuable if designed to bring out in orderly fashion the practices of growers and the factors that govern those practices. Mere sightseeing is no substitute for planned observation and analysis.

Methods of study. The student must exercise care and diligence in study corresponding to the care that has been taken to make each sentence in this book say what is intended. The story-book type of reading is not sufficient. After a straight-through reading of a section of the text, it is well to go back and find the crucial points and then to study these intensively, building an orderly mental picture. The student should be sure to look up unfamiliar words. Many students find marginal markings or underscoring helpful in first study and even more helpful in review. Brief note-taking serves the same purpose if the student does not own a copy of the book.

There is no substitute for hard study, nor any painless way to gain an education. Orderly, intensive mental effort is the price of understanding, and at the same time it makes learning easier and contributes a feeling of mastery. For suggestions on methods of study see any of the good little books or pamphlets on the subject, notably *Studying Effectively* by Wrenn and Larsen, Stanford University, Palo Alto, California.

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Associated Seed Growers

1

Vegetables in Life and Agriculture

The people of the United States probably make fuller use of vegetable food than the inhabitants of any other land on the globe. Formal education and publicity dealing with the nutritive values of vegetables have contributed to this most desirable situation, as have relative prosperity and the fact that these foods are well liked by most people.

Accordingly vegetable production plays a major part in the agriculture of the United States, producing about 15% of the dollar value of crops sold. Cash income from vegetables including potatoes, sweet potatoes, and dry beans has, in years of good prices, reached a level of $1,700,000,000. To this might be added $400,000,000 estimated as farm value of vegetables consumed in farm homes There is no estimate for other home garden production.

What is a vegetable?

No satisfactory definition for the word vegetable has been devised. There are exceptions to any attempt to separate vegetables from other plants and plant products. Most vegetables are served with the entree or main dish of a meal, but some are used for dessert and for salads. The tomato is, botanically, a berry; sweet corn is a cereal. The muskmelon is considered a vegetable but the strawberry is not. The culinary herbs are usually included among the vegetables. All the plants are herbaceous. Most vegetables are annual or biennial; a few are perennial. The mushroom is a fungus. Intensiveness of culture is not a good guide, as many vegetables are grown on an extensive field scale. Olericulture, of Latin derivation and used by some professors, means vegetable culture. Bailey, in *Prin-*

ciples of Vegetable Gardening, lists 247 vegetables. Some 30 or 40 are of considerable commercial importance.

FOOD VALUES OF VEGETABLES

Vegetables are of high food value; Fig. 1.1 shows the esteem in which they are held by nutritionists. The various kinds of vegetables vary widely in their energy values, some, like pota-

USDA

FIG. 1.1. Nutrition chart. Note prominent place assigned to vegetables.

TABLE 1.1. NUTRITIVE VALUES OF VEGETABLES

100 Grams (3½ Ounces) Uncooked Edible Portion	*Moisture %* (approx.)	*Cal-ories*	*Pro-tein,* gm.	*Fat,* gm.	*Carbo-hydrate,* gm.	*Cal-cium,* mg.*	*Phos-phorus,* mg.	*Iron,* mg.	*Vitamin A,* I.U.*	*Thia-mine* (B_1), mg.	*Ribo-flavin* (B_2), mg.	*Ascorbic Acid* (C), mg.
Asparagus	93	21	2	0	4	21	62	1	1,000	0.16	0.19	33
Bean, snap	89	35	2	0	8	65	44	1	630	0.08	0.11	19
Beet	88	42	2	0	10	27	43	1	20	0.02	0.05	10
Broccoli	90	29	3	0	6	130	76	1	3,500	0.10	0.21	118
Cabbage	94	14	1	0	2	43	41	1	260	0.03	0.04	31
Carrot	82	42	1	0	9	39	37	1	12,000	0.06	0.06	0
Celery, blanched	94	18	1	0	4	50	40	1	0	0.05	0.04	7
Cucumber	96	12	1	0	3	10	21	0	0	0.03	0.04	8
Lettuce, head	95	15	1	0	3	22	25	1	540	0.04	0.08	8
Muskmelon	94	20	1	0	5	17	16	0	3,420	0.05	0.04	33
Onion, mature	88	45	1	0	10	32	44	0	50	0.03	0.04	9
Pea, green	74	98	7	0	18	22	122	2	680	0.34	0.16	26
Pepper, green	92	25	1	0	6	11	25	0	630	0.04	0.07	120
Potato	78	83	2	0	19	11	56	1	20	0.11	0.04	17
Radish	94	20	1	0	4	37	31	1	30	0.03	0.02	24
Rhubarb	95	16	1	0	4	51 †	25	0	30	0.01	0	9
Spinach	93	20	2	0	3	81 †	55	3	9,420	0.11	0.20	59
Squash, summer	95	16	1	0	4	15	15	0	260	0.05	0.09	17
Squash, winter	89	38	2	0	9	19	28	1	4,950	0.05	0.12	8
Sweet corn	74	92	4	1	21	9	120	1	390	0.15	0.12	12
Sweet potato	69	123	2	1	28	30	49	1	7,700	0.09	0.05	22
Tomato	94	20	1	0	4	11	27	1	1,100	0.06	0.04	23
Turnip	91	32	1	0	7	40	34	1	0	0.05	0.07	28
Turnip greens	90	30	3	0	5	259	50	2	9,540	0.09	0.46	136
Watermelon	92	28	1	0	7	7	12	0	590	0.05	0.05	6
Other foods for comparison												
Bread, white, enriched	35	275	9	3	52	79	92	2	0	0.24	0.15	0
Milk, whole	87	69	4	4	5	118	93	0	160	0.04	0.17	1
Beef, round steak	69	182	20	11	0	11	180	3	0	0.08	0.17	0
Egg, whole	74	162	13	12	1	54	210	3	1,140	0.10	0.29	0
Apple	84	58	0	0	15	6	10	0	90	0.04	0.03	5
Orange	87	45	1	0	11	33	23	0	190	0.08	0.03	49
Allowances for a man (143 lb.) per day ‡												
Age: 25 years		3,200	65			800		12	5,000	1.6	1.6	75
Age: 45 years		2,900	65			800		12	5,000	1.4	1.6	75
Age: 65 years		2,600	65			800		12	5,000	1.2	1.6	75

* mg. = milligrams. I.U. = International units. † Not fully available because of oxalic acid content.
‡ Allowances for women and children from mimeographed publications by Food and Nutrition Board, National Research Council, 1953.
Table from Composition of Foods, USDA Agr. Handbook 8, 1950.

toes, being high in carbohydrate, others, like lettuce and cucumbers, being low. In general, fresh or processed vegetables are high in minerals and vitamins and low in protein and fat, and they are valuable for palatability and bulk. Dried peas and beans are high in protein.

Table 1.1 shows nutritive values of the leading vegetables, comparing them with other important foods and with the daily allowance for man. Actual values vary widely, and available data in some cases are meager. The importance of niacin or nicotinic acid is being recognized, but data are still scarce.

Books and bulletins on nutrition should be consulted for further study of the nutritional value of vegetables.

Recognition of food value. The use of vegetables as food has increased greatly during the past few decades. Fewer people are living on inadequate diets of meat, potatoes, and cereals, of fat bacon and corn, of fish and rice. Unconsciously many people have learned by experience the need for other nutrients as evidenced by the use of various wild or cultivated herbs and plants in Asia and Africa and the traditional use of turnip greens and collards in our own southland. But some families everywhere and the people of some whole areas are still suffering from deficiency in one or more of the requirements for a balanced diet. This may be the result of poverty or of inability to plant and protect a garden, but more often the major causes are ignorance and neglect. Most people like vegetable food, yet experts in nutrition tell us that even in this country we use only half as many vegetables as would be good for us. The teaching of the culture and use of vegetables is greatly needed throughout the world.

High yield per unit area. Vegetables should be more widely recognized and used the world around, not only (1) because they taste good and (2) supply both basic and accessory nutrients, but also (3) because they furnish maximum quantity of food for the area planted, and (4) because they grow quickly. This holds true without questioning the supremacy of wheat, corn, and rice as human foods which are not likely to be displaced. Table 1.2 compares acre yields of carbohydrate and protein for wheat, potatoes, and carrots.

As limitations on their use may be mentioned (1) high water content, (2) highly perishable nature for transport and storage,

and in some cases (3) high man-hour requirement for production and handling.

Even though vegetables are generally low in protein content they have proved highly valuable in situations of marginal food supply and of actual famine. During World War I, Germany made extensive use of turnips, because they grow quickly and their yield of bulk, carbohydrates, and other nutritive materials

TABLE 1.2. FOOD VALUES ON PERCENTAGE AND ON ACREAGE BASIS

	Percentage			*Yield per Acre, lb.*		
	Water	*Carbo-hydrate*	*Protein*	*Total* *	*Carbo-hydrate*	*Protein*
Wheat	14	67	12	1,000	670	120
Potato	78	18	2.2	14,000	2,520	308
Carrot	88	8.2	1.1	18,000	1,476	196

* Approximate United States average yields.

is heavy in relation to the area planted. In some of our own southwestern states in 1934, drouth was serious, but rains came in time for turnips to mature before frost.

Efficiency in food production. Studies by MacGillivray and others (cf. ref. 3) have undertaken to appraise the efficiency of the various vegetable crops as producers of nutritive values in relation to acreage and man power required. Ratings are assigned to the crops on the basis of nine nutritive elements, including energy, protein, minerals, and vitamins, and also on the basis of yield of edible product, land occupied, and labor required. Using such data MacGillivray and his co-workers have arranged the crops in four groups as shown in Table 1.3. They recognize that such studies cannot be conclusive because of widely varying production conditions, and because of the impossibility of including all nutritive values or of appraising them numerically in relation to one another. Such studies are valuable, however, in focusing the attention upon the crops that yield the most in food value at the lowest cost. A similar study was made by Christensen of the U. S. Department of Agriculture.

TABLE 1.3. OVER-ALL CLASSIFICATION OF VEGETABLES BASED ON THEIR RANKS IN NUTRIENTS PER POUND, PER ACRE, AND PER MAN-HOUR, 31 CROPS[11]

GROUP 1

Crops Ranking 1–15 in Nutrients per Pound, Acre, and Man-Hour

Broccoli	Sweet potatoes
Cabbage	White potatoes
Mustard	Winter squash
Spinach	

GROUP 2

Crops Ranking 1–15 in Two of the Following: Nutrients per Pound, Acre, or Man-Hour

Beets, bunch	Late onions
Brussels sprouts	Tomatoes, market
Carrots, bunch	Turnips, bunch
Early onions	

GROUP 3

Crops Ranking 1–15 in One of the Following: Nutrients per Pound, Acre, or Man-Hour

Artichokes	Lettuce
Cauliflower	Lima beans
Casabas and honeydews	Peas
Celery	Snap beans
Green asparagus	White asparagus

GROUP 4

Crops Ranking 16–31 in Nutrients per Pound, Acre, and Man-Hour

Bell peppers	Summer squash
Cantaloupe	Sweet corn
Cucumbers	Watermelon
Radish	

VEGETABLES IN AGRICULTURE

Since vegetables are of such importance in the nutrition of human beings, it is natural that they should play a large part in American agriculture.

For home use. Countless farmers and others could improve both their diet and their economic position by growing more vegetables and by preserving and using them throughout the year. The peas or tomatoes that a farmer sells for 4 or 5 cents

come back to him or to other farmers in cans at 18 to 20 cents, and many farm families do without because they cannot afford to buy them or because they do not know and think and act. Home production by-passes the costs of processing, packaging, shipping, and merchandising. A quarter-acre garden readily produces vegetables that would cost $100 to $200 at retail.

FIG. 12 Violet Murray and Carol Apple demonstrate salad making at Indiana Muck Crop Show This is excellent training for young people and a fine way to promote use of vegetables

For market. Modern civilization leaves millions of people in situations where, under normal conditions, they cannot grow vegetables or they find it preferable to buy their supplies. To meet these needs the commercial vegetable business has grown up, with its local gardeners, its shippers or truck farmers, and its growers of crops for canning and other processing.

Potatoes and sweet potatoes are being used for industrial purposes, largely as sources of starch. Research is in progress and has already found new uses for vegetables.

The importance of any branch of farming may be expressed in many ways, the principal ones being dollar value, acres of land (or number of animals), tonnage of products, and number of farms or farmers involved.

TABLE 1.4. VEGETABLE CROPS IN THE UNITED STATES

Cash Farm Income from Marketings by Farmers

Does not include crops fed to animals or products used as human food on farms.

Crop	*1940*	*1950*	*1951*	*1953*
		$1,000,000's		
1. Truck crops *	353	900	1,137	1,220
2. Irish potatoes	154	348	357	330
3. Dry beans	41	111	118	144
4. Sweet potatoes	18	40	44	49
5. Total vegetables	571	1,408	1,656	1,757
6. Total fruits and nuts	417	1,290	1,214	1,228
7. All crops marketed (crops fed not included)	3,435	12,352	13,052	14,149
8. Livestock and livestock products	4,897	15,976	19,569	17,263
9. Total	8,332	28,328	32,622	31,413

USDA Bur. Agr. Economics, mimeographs.

Vegetable Farms and Acreage

	1949
10. Number of farms	5,400,000
11. Acres all crops	344,000,000
12. Farms reporting vegetables for sale †	347,000
13. Acres of vegetables for sale	3,718,000
14. Farms reporting Irish potatoes ‡	1,649,000
15. Acres of Irish potatoes ‡	1,514,000

U. S. Census 1950.

* Includes crops for processing and fresh use.
† Not including Irish potatoes, sweet potatoes, or dry beans.
‡ No distinction between commercial and home use.

It is important in reading tables to observe critically the notes which tell just what is included and omitted and also the basis and origin of the figures. Most apparent discrepancies can be

accounted for in one way or another. Remember that wide year-to-year fluctuations are characteristic of the vegetable business.*

Tables 1.4 to 1.6 are designed to give a picture of vegetables as a part of American agriculture. Teachers will do well to

TABLE 1.5. LEADING VEGETABLE CROPS IN ORDER OF FARM VALUE, 1953

Crop		*Acres,* 1,000's	*Production,* 1,000 tons	*Farm Value,* $1,000,000's
Potato		1,508	11,211	341
Tomato	Mkt.	236	902	128
	Proc.	292	3,242	89
Lettuce		210	1,403	121
Sweet potato		350	1,019	89
Snap bean	Mkt.	159	262	47
	Proc.	138	299	37
Sweet corn	Mkt.	216	599	46
	Proc.	502	1,505	35
Cantaloupe		141	549	57
Celery		37	718	53
Carrot		82	781	52
Pea	Mkt.	13	20	3
	Proc.	431	462	44
Watermelon		435	1,356	43
Cucumber	Mkt.	49	177	21
	Pickles	151	332	21
Cabbage	Mkt.	152	1,228	35
	Kraut	17	212	3
Onion		132	1,236	37
Asparagus	Mkt.	46	58	15
	Proc.	89	94	19

USDA Agr. Marketing Service, Crop Reporting Board, 1953.

revise figures each year using sources indicated here and in the reference list at the end of Chapter 1.

* One way to smooth out fluctuations and detect trends is to use 5- or 10-year averages. Another is to use "rolling averages." Thus the average for 1947–1951 would be plotted for 1949, the average for 1948–1952 for 1950, and so on.

A weighted average for, say, yield or price takes into account the quantity involved in each figure. Thus the average of two prices, $1.50 and $2.50 per bushel, would be $2.00. But if 300 bushels were sold at $1.50 and 100 bushels at $2.50, the weighted average would be $1.75 a bushel.

TABLE 1.6. LEADING VEGETABLE STATES IN ORDER OF FARM VALUE, 1953, $1,000,000's

State	*Potatoes*	*Sweet Potatoes*	*Truck Crops* (fresh and processing)	*Total*
California	44	6	324	374
Florida	16	3	121	140
New York	23	..	61	84
Texas	2	7	61	70
New Jersey	6	8	50	64
Wisconsin	17	..	30	47
Idaho	41	..	4	45
Arizona	3	..	42	45
Michigan	12	..	32	44
Pennsylvania	18	..	23	41
Maine	32	..	3	35
Oregon	11	..	23	34
North Carolina	6	12	15	33
Washington	8	..	23	31
Ohio	7	..	23	30
Colorado	15		13	28
Virginia	7	5	15	27
Georgia	1	7	18	26
Minnesota	11		13	24
Louisiana	1	18	5	24
Maryland	1	3	18	22
South Carolina	2	7	13	22
Indiana	5	..	17	22
Illinois	1	..	21	22

USDA Agr. Statistics, 1953.

Conversion factors, weight per bushel or package, are given in *Agricultural Statistics*, an annual publication of the U. S. Department of Agriculture.

Home gardens. No adequate data are available on home gardens. The U. S. Department of Agriculture estimates indicate the value of products of farm gardens at farm prices (not retail) as about $400,000,000 annually.

Comparisons

Dollar values. Vegetables, including Irish potatoes, sweet potatoes, and dry beans, represented a farm value of $802,000,000 in 1929, $361,000,000 in 1932, $589,000,000 in 1939, and $1,598,300,000 in 1953. Many industries are rated at the retail value

of their products. This basis would probably nearly triple the 1939 figure to roughly $1,700,000,000 compared with $8,000,000,000 worth of all goods sold in food stores in a pre-war year.

Compared with other branches of agriculture, vegetables have ranked in farm value alongside cereals and cotton, sometimes ahead, sometimes behind. Meat, dairy, and poultry products show much higher figures, but they represent crops processed through feeding to animals.

Per capita consumption of potatoes, other vegetables, and other foods has shown marked changes since the early 1900's. There has been a notable increase in the use of fresh vegetables from 188 pounds per capita in 1918 to 251 in 1949, with a corresponding increase in the use of processed vegetables. The use of Irish potatoes declined from 193 pounds per capita in 1909 to 108 in 1949, and the use of cereals decreased almost as much. These figures reflect a growing appreciation of the values of the miscellaneous vegetables in nutrition, in palatability, and in variety.

Land area. The vegetable business makes far less of a showing in terms of land than in terms of dollars. An acre normally produces about $35 worth of wheat, $80 of cotton, or $200 of vegetables. Accordingly, our supply of all vegetables comes from only about 7,500,000 acres compared with 87,000,000 corn acres, 63,000,000 wheat acres, and 21,000,000 cotton acres.

Tonnage of all vegetables is high: 27,000,000 tons against 39,000,000 tons of wheat. Truck crop tonnage had risen to 16,000,000 tons in 1952. Vegetables carry much more water than grain or cotton.

Farms. The vegetable business, however, does not involve as many farms or people as cotton and cereals—nor as many votes. The Census of 1950 reported 347,000 farms as growing miscellaneous vegetables for sale. The potato and sweet potato figures, 1,650,000 and 786,000 farms respectively, include those producing for home use as well as for sale. There are about 5,400,000 farms in the United States.

The vegetable business contributes heavily to and draws heavily upon the many industries and trades that serve it: processors; produce dealers; transport carriers; seedsmen; makers and dealers in fertilizer, insecticides, fungicides, and herbicides, implements and equipment, packages, and other marketing supplies.

KINDS OF VEGETABLE PRODUCTION

Market production. The vegetable-producing business is too varied in nature to permit a single description or even a good classification. Formerly fairly sharp distinctions separated the *market gardener,* who grew intensively for the local market, from the *truck farmer,* who produced extensively for long-distance shipment. Today, the local grower is more specialized and less intensive than formerly and may ship some of his product. The long-distance man may operate as intensively as any nearby gardener. The many *general farmers* who grow one or two vegetables as part of the farm enterprise have become an important factor in our vegetable supply. Dairy farmers have long grown potatoes or cabbage, but now they may produce sweet corn, peas, beans, squash, or cucumbers for market and may contract to deliver crops to a cannery or other processor. Many growers produce beef animals as well as vegetables.

The vegetable business ranges from little patches of crops from which a few vegetables are taken to market during the peak season to great factory farms, highly organized and mechanized.

Geography. Operations on large scale and small are to be found in all sections of the country—north, east, south, and west. See end-paper map. By no means are all the California growers big operators, and many large enterprises are to be found in the northeastern states, some in mountain valleys as well as along rivers or on coastal plains. Many small Texas farmers bring cabbage to the packing house in a pickup truck, a trailer behind the family car, or even in the back of a sedan. King Farms of eastern Pennsylvania roll trucks anywhere within the Albany-Washington-Cincinnati-Cleveland area, and many farmers go faithfully with small and varied loads to curb or covered markets in Lancaster, Akron, or Atlanta. San Francisco and Sacramento have cooperative markets serving many small-scale local gardeners.

Vegetables for processing are generally grown on a non-intensive low-cost basis. The price per ton is low and returns per acre are usually small, but special measures to increase yields help greatly in lowering the cost per ton.

The four principal forms of processing vegetables for home or commercial purposes are canning, freezing, dehydration, and pickling or fermentation. Each of these forms represents a method of curbing deterioration due to organisms (fungi, molds, bacteria), enzymes, oxidation, and other chemical changes and evaporation.

1. *Canning* is by all odds the most important method of processing vegetables. The principle involved is the sterilizing or destroying of all living organisms in the vegetables and keeping them sealed in cans, usually of tin or glass, to prevent reinfection. Cheap, unrefrigerated storage serves well, and special facilities in transit and in stores are not required.

2. *Freezing* has become important both for commercial and home preservation, reaching in 1951 a production or pack level 10% as high as canning. Commercial freezers have devoted special attention to use of high-quality varieties, harvesting at the proper stage of maturity, and quick handling and freezing, all of which contribute to the excellence of the product. On the other hand, costly low-temperature facilities are required for storage, transit, and retailing.

3. *Dehydration* is an ancient and primitive form of preservation, valuable where facilities for canning and freezing are unavailable or too costly, especially in regions of dry atmosphere It preserves by reducing moisture content so that destructive organisms cannot grow. Dried vegetables may be protected from moisture and insect or other predators by sealing in containers of metal, glass or pottery. During World Wars I and II dehydration and re-freshing processes were greatly improved to bring greater palatability while taking advantage of low bulk for transport and storage. The method is of no great commercial importance for vegetables in the United States in peacetime.

4. *Pickling and fermentation*, including the making of sauerkraut, hold an established but minor place. Preservation is by establishing a concentration of salt or acid too high to allow destructive organisms to work. These methods, with brining, may prove important in lands where canning costs are prohibitive and where climate is too warm for fresh storage.

In processing blanching is an important means of inactivating enzymes and of fixing color and flavor. It is accomplished by a brief precooking by steam or hot water.

Each form of processing has come as an innovation, has gained rapidly, but has gradually found its level according to kinds of products, climate, economic conditions, and other factors. Thus tomatoes, peas, beans, and sweet corn are the great cannery crops. Cabbage is processed by fermentation into kraut. Potatoes, cabbage, carrots, and onions are sometimes dried but canned only to a limited extent. Lettuce and muskmelons are seldom processed at all. We may expect changes in these relations, but each form of processing is likely to continue in use, each in its own place.

C W Zuck and Sons, Erie, Pa

FIG. 1.3 Greenhouses for vegetables.

Vegetables for processing are often bought on contract between manufacturer and farmer, entered into before crops are planted. Grower cooperatives are in some places doing good work in bargaining with processors.

Vegetable forcing or culture of vegetables under glass is highly developed along Lake Erie from Erie to Toledo, although there are important districts elsewhere.

In greenhouses, operating costs are very high, around $12,000 to $15,000 per acre per year. Depreciation, heat, and labor are costly items. The ready transport of outdoor products from south and west has brought keen competition. Few vegetable greenhouses have been built of recent years. Where a good range of glass has been amortized over a long period of years, thus cutting overhead cost, profitable production may be maintained.

Hothouse quality still holds a place on fancy markets, and good managers still make a profit. The tomato is the principal

crop; the cucumber, second. Lettuce, radish, parsley, cress, beet greens, and others are grown in the winter. The tomato does well because the quality is generally superior to that of fruits picked green and ripened artificially.

The value of mushrooms cultivated in special houses in 1949 exceeded hothouse tomatoes in value of product, about $15,000,000. See "Mushroom growing in the United States," *USDA Bulletin* 1875, 1941, and other special bulletins and books on this subject.

The production of vegetable seeds and the **growing of plants** to sell are important branches of the vegetable business; see Chapters 8 and 9.

OPPORTUNITIES

A major concern of young people is opportunity, a chance to make a good living and to live a good life.

The business of growing vegetables has been shown to be an important part of agriculture and to have an important place in supplying needed food to human beings. This being so, many people will continue to grow vegetables to sell and many will be engaged in the auxiliary businesses that serve vegetable growers.

Opportunities in production

Under normal conditions, the consumption of vegetable foods is not likely to decline. On the other hand, competition is keen in vegetable production. When prices are good, it is very easy for farmers to take up the production of vegetables, after a fashion. Similarly, when prices are low, it does not take long to quit. Thus, we are viewing a field of agriculture in which adjustments are rapid.

The backbone of the vegetable industry consists of large numbers of steady, intelligent growers who adjust gradually as conditions change but who do not increase or decrease their operations greatly from year to year. The vegetable business as a whole has shown greater stability under boom and depression than the other branches of agriculture, not rising so high, relatively, as cotton, corn, wheat, or meat, and not falling so low.

It is not much of a trick to grow vegetables and to sell them at low prices at peak season through conventional channels but this

kind of enterprise ordinarily does not yield satisfactory returns—is not really successful.

Three basic requirements for success in production are:

1. Good location.
2. Better than average management in production and selling.
3. Low costs.

Real success requires that one make a good job, not of the easy enterprise, but rather of the difficult one. This means producing quality for discriminating trade, or maturing crops when supplies are likely to be low, or achieving maximum yield at minimum cost. The last is important because a large share of our people must buy at relatively low prices. A good though not necessarily a fancy job of preparing, packing, and selling is no less important. In general, the low-quality demand is larger in volume, but is sooner oversupplied, than the demand for first-class goods. De luxe or superquality demand pays well but is limited in volume and may require excessive costs.

Advantages of local markets. Since the greatest item in cost of distribution of goods is labor, the difference between farm price and retail price of vegetables is wide. Hence, one may well consider a form of vegetable production that enables him to realize a good share of the retail price. Roadside selling and local marketing are good in this respect, though, of course, selling costs are higher than if produce is sold wholesale. There are many towns of 5,000 to 25,000 people that do not have an adequate local supply of vegetables and that offer real opportunities. Many communities do not have a single good grower-operated roadside stand.

Opportunities in business

Commercial vegetable growers ordinarily receive annually over $1,500,000,000, sometimes $2,000,000,000. Much of this must be spent for equipment, supplies, seed, and other requirements. These fields along with the enterprises of marketing and processing require men who are well trained in the basic sciences and who know their agriculture as well. The marketing inspection services, conducted by government, by railroads, and privately, use large numbers of trained men.

Opportunities in research and education

Extension work, teaching, and research activities concerned with vegetables are expanding yearly, partly because these services are increasing for all agriculture and partly because the vegetable business is now demanding and receiving the service that it needs and has not enjoyed in the past These services require scholarly men of high ability and with the best of training. The needs of foreign lands are likely to call many good workers.

TRAINING FOR OPPORTUNITIES

Education for life calls for (1) training that will help one directly in his chosen calling vocational training, (2) basic

FIG. 14 Student laboratory gardens at Cornell

courses that will increase his understanding of the factors of chemistry and physics and biology that govern his crops; and, no less, (3) cultural courses that will help him to enjoy a full, well-rounded, satisfying life These ideals may be reached (or missed) at high school or at college or at graduate levels Equally essential is proper motivation: a desire to succeed, to achieve satisfaction, and to serve one's fellow men

Practical experience is part of well-rounded training, whether for farming or for other service. It is not a substitute for school work. It helps the student to understand his course work and to apply intelligently the things that he learns.

Among the attributes that contribute to personal success in vegetable production are:

1. Thorough and up-to-date knowledge of crops, problems, and methods.
2. Willingness to explore new ideas, to think things through, to plan.
3. Studious attention to the marketing situation.
4. Readiness to cooperate with neighbors and others.
5. Familiarity with services available and readiness to use them.

ANALYSIS OF PROBLEMS

The object of the vegetable grower is to realize a good living and a good life through serving the food requirements of the consuming public. To this end, a margin of profit should remain after all costs are met.

The problems that face the grower of vegetables may be presented in outline as follows:

A. Production operations are directed toward:

1. High yield at low cost per unit of product.
2. High quality to command ready sale and a good price.

We further these ends by:

1. Modifying conditions of plant *environment*, including soil factors, moisture, weeds, insects, and diseases, and many others.
2. Planting well-bred stocks, of fine *heredity*.
3. *Adjusting ourselves* and our operations to conditions which cannot readily be changed, such as climate, weather, prices, and some enemies.

B. Selling operations aim to:

1. Retain quality unimpaired, as nearly as possible, through to the housewife's kitchen.
2. Find the most favorable market.
3. Get the best price available on that market.

C. Business management.

Includes matters of investment, interest and depreciation, credit, labor management, costs and returns.

HOW TO ATTACK PROBLEMS

Resources for the planning of operations

1. Use of textbooks and notes from courses.
2. Articles and hints in farm and trade papers.
3. Bulletins of the experiment stations.
4. Consultation with successful growers, extension specialists, county agricultural agents, commercial tradesmen, and wholesale and retail buyers. This embraces the composite experience of a region.
5. Resources of one's own experience. Keeping of notes and records redoubles the usefulness of experience.

In using all these, consider applicability to your own situation. A Maine potato bulletin might not be of much use to a Californian in solving his fertilizer problem, but it might be valuable on spacing or packaging.

Steps in good planning

1. Know the principal facts about climates, lands, crops, markets, and economic factors.
2. Analyze the whole situation, giving proper weight to pros and cons, to favorable and unfavorable elements.
3. Decide specifically on the plan of procedure, and put it down on paper. This is a valuable aid to clear thinking and serves as a memorandum and record.
4. Be ready to change the plan, since many factors may change as time goes on.

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Among scientific journals containing papers on vegetable plants and crops are: *American Journal of Botany, Botanical Gazette, Economic Botany, Food Industries, Food Research, Journal of Genetics, Plant Physiology, Soil Science*, and others.

Among valuable indexes and abstract journals are: *USDA Bibliography of Agriculture, Biological Abstracts*, and the *Wilson Index of Periodical Literature.*

2

Growing Vegetables for Home Use

The value of an acre wisely developed as a home garden can be made about ten times as great as that of the same area devoted to ordinary farm crops.—L. C. CORBETT, *Garden Farming*, page 105.

A small investment of time, energy, and cash in a home vegetable garden does more to improve the standard of living of a

FIG. 2.1. A big farm garden—vegetables to eat, can, and freeze.

family than almost any similar outlay. It takes much labor to produce a 40-quart can of milk, a bushel of wheat, or a bale of cotton. But a can of milk will ordinarily buy only 15 or 20 No. 2 cans of vegetables; a bushel of wheat, only 10 or 12 cans. This is a cold dollars-and-cents calculation.

One of the great advantages of living on a farm is to have quality products at low cost right at home. The tasty freshness of garden salads, the tender sweetness of Golden Cross sweet corn, the flavor of newly harvested asparagus cannot be matched in the stores, and many nutritive values also decline during the marketing process. Nor are the hungry boys around the table limited to tiny restaurant portions when the garden supports the table.

Economic importance. A good gardener not infrequently harvests $200 worth of vegetables, figured at retail prices, and some are able to double this figure. While there is no adequate statistical information on home gardens, the U. S. Department of Agriculture estimates the value of vegetables from farm gardens in 1951 at about $100,000,000,* or an average of about $75 per garden for all farms This is at farm prices; retail value would be two or three times as great. And there are thousands of farms that have no garden at all. In the 1940 census, 2,200,000 farmers, nearly 37%, out of a total of about 6,000,000 did not report gardens.

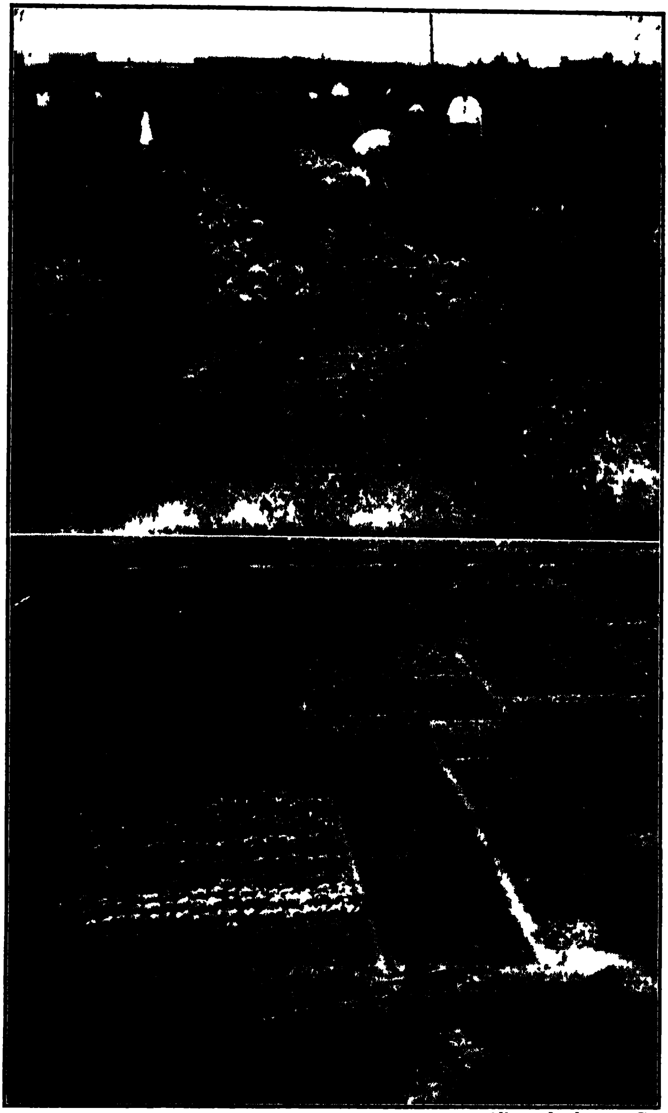
A garden is feasible and profitable almost anywhere, especially if people realize its value in health and good living and are willing to make the effort to have one. In some places, on account of climate, enemies of various sorts, and other difficulties, it is not easy to have a good garden. Werner[5] has written a bulletin that contains valuable suggestions for growing vegetables for home use in semi-arid country where gardening presents problems. (See also ref. 11.4.)

School gardening. Among the educational advantages a garden provides is training in knowledge and management of plants. A garden is well adapted for 4-H and Future Farmer projects and, especially in villages and suburbs, for recreation.

Maintenance of a garden is a splendid adjunct to a course in vegetable crops, either as a formal school laboratory exercise, or as a project, or just as a garden at home. Gardening affords the opportunity to apply the things learned in school, to get an idea as to which teachings apply locally and which do not, and, in general, to add interest and a feeling of reality to the course.

For school projects, it is usually better to have gardens at home than in large centers or in community gardens, though school

* *USDA Agr. Statistics,* **1952, p. 692.**



Albert Dickinson Co.

FIG. 2.2. Community gardens are very useful where space is not available at home. The two above are sponsored by a commercial concern for its employees.

gardens have a useful place if plantings can be made long enough before term-end. Decentralizing the gardens increases the job of supervision, but such gardens are better cared for and are at the place where food will be used conveniently and when at its best. The same principle applies to enterprises for unemployed or factory groups. Great layouts of community gardens are not as common today as in 1918 or 1933, although they still have their place.

The chapter on home gardens comprises only a few pages of this book, but most of the text applies to home as well as to commercial gardening. If one learns the nature of the vegetable crop plants, their requirements, and the ways of growing them, he will have little trouble in choosing suitable methods for the home garden. Study applicable parts of Chapters 6 to 11 and the crop chapters.

Sources of information. The U. S. Department of Agriculture and most of the states have excellent bulletins on vegetable culture, cookery, and processing.* State bulletins suggest methods well adapted to the area in question, but there is a wide range of soil and climate even within a state, from coast or plain to mountain valleys and slopes. Thus, the home gardener needs to understand his plants and soil and climate and to use his own judgment rather than to follow slavishly any set of precise directions.

Location

A good garden location should be:

1. **Near the house** for convenience in working at odd times and in harvesting.

2. **On suitable soil.** Preferably the soil should be loam or sandy loam; however, with proper treatment and care almost any soil will do. It should be well drained, not too acid, and well supplied with organic matter and nutrients. See Chapter 10.

3. **With proper exposure and shelter.** A slope to the south or southeast favors earliness, and a building or shelter belt on the windward side is a real help in many climates. On the other

* The term "processing" will be used to cover canning, freezing, drying, and pickling for home and commercial purposes.

hand, shade is a serious obstacle, and roots of trees or hedges often rob a garden of needed moisture.

4. **Within reach of water.** This is of major importance in semi-arid or arid regions, but water will help a garden greatly almost anywhere. The garden can often be located to use surplus water from the supply for house and barn, or water diverted from a little stream and distributed between rows by western furrow irrigation methods. Pumping is not expensive, and it is not difficult or costly to have the farm pump a little oversize to keep a 50 by 50 foot patch watered as needed. At the same time countless gardens in humid climates are successful without artificial watering.

Planning

Garden planning is directed toward an adequate supply of vegetable food through as long a season as possible.

Choice of crops to plant and arrangement of plantings in the garden are exceedingly flexible. Basic nutritional needs, what the family likes, and what grows well in a given locality are primary factors to consider.

Some farmers like to have two garden plots, using them alternately, in the interest of better control of weeds. This permits growing green-manure crops on one plot each year.

Do not plant more in April than you will care for in July. It is much better to have a small garden with a few easily grown, sure-fire crops and to care for it well than to attempt too elaborate a crop plan. A surprising supply of vegetables may be obtained from a plot 25 by 25 feet or even smaller. One may also plant a larger garden of the coarser growing crops, planned for horse or tractor cultivation. It takes only a few minutes to go through a patch of peas, sweet corn, beans, cabbage, potatoes, and tomatoes. These may be planted alongside a field of some row-crop such as corn or potatoes.

Perennial crops such as asparagus and rhubarb, as well as the bush fruits and strawberries, may well be at one side of the garden. Plant early-maturing crops together so that the land may be easily replanted or used for a cover crop.

Make a plan on paper to provide for suitable succession and variety of products, and to furnish a basis for the seed order. The plan may take the form of a map or of a table showing

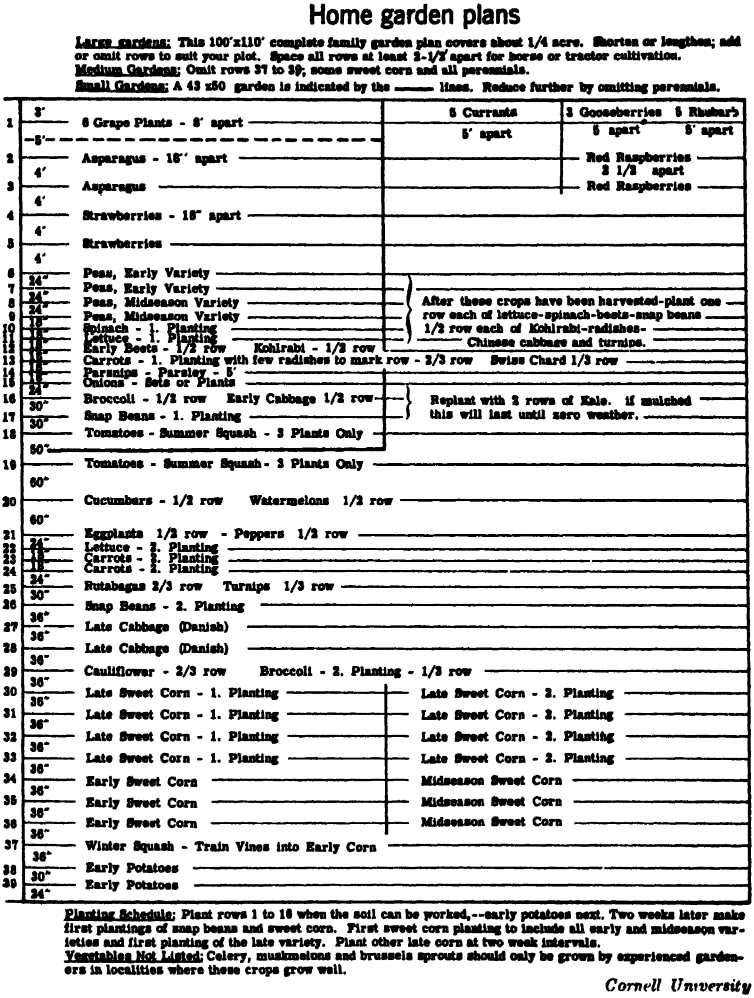


FIG. 2.3. A garden plan. Layouts of gardens vary widely according to climate, soil, and family needs. This plan is given as an example. For planting rates and quantities see Table 11.3. For planting dates consult state bulletins or garden advisors.

kind, variety, source, length of row, and date of planting, with space for harvest record and other notes. See Fig. 2.3.

Varieties should be selected for table quality and suitability for processing and storing as well as for adaptability to local conditions, productiveness, and earliness. See crop chapters.

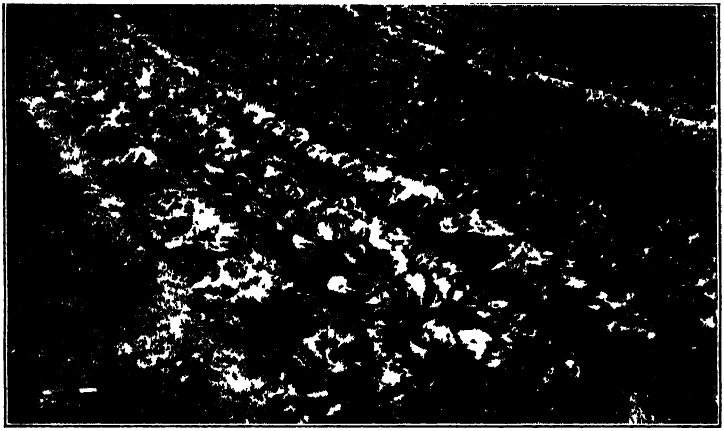


FIG. 2.4. Plant for early maturity In this northern garden, lettuce, radishes, onions, and spinach were ready in May; beets, peas, and cabbage in June.

Extend the planting season. A common mistake is to plant the garden all at once, usually much later than desirable. Other farm work may tend to crowd out or postpone the making of a garden, but the number of hours required is really small and there is little work that one can do that will yield more in good living. The season of harvest may be lengthened by using early varieties and transplanted plants. A northern garden planted over a period of 16 weeks has produced vegetables from June 1 or earlier to November 1 or later.

Fertility

In most cases a heavy application of stable manure, say 20 tons per acre,* plus 40 pounds of 20% superphosphate per ton of manure will maintain fertility and even improve it. If manure is not available cover crops such as rye or rye grass

* An acre is 43,560 square feet. Pounds per acre divided by 400 is roughly equivalent to pounds per 100 square feet.

and a well-balanced commercial fertilizer will serve well. Such ratios as 1–1–1, 1–2–1, or 1-2–2 may be used. See page 181. Annual application of 1,200 to 1,800 pounds per acre of a 10–10–10 or 5–10–5 or 5-10–10 fertilizer is usually adequate.

After early vegetables are harvested, green-manure crops may be planted in part of the garden. Half of a large garden block may be allotted to the green-manure crops for the full season of each year; a bit of fertilizer will help them and will not be lost to the garden. Crop residues, such as cabbage stumps and leaves, cornstalks, and pea and bean vines, should be plowed or spaded in. Disease danger from this practice is not commonly serious

Composting. In town, leaves, lawn rakings, and crop residues may be plowed or spaded into the soil or they may be accumulated and composted, making a compact heap; the pile should be kept moist, and about 150 pounds per ton of a mixture such as the following should be added:

	Pounds
Ammonium sulfate	45
Finely ground limestone	40
Superphosphate 20%	15

This supplements the nutrients of the compost and hastens decomposition.

Liming. Never use lime or wood ashes unless a soil test shows the need for them. Need for lime can be learned by consulting the county agent or vocational teacher. Most vegetables grow best in a slightly acid soil, one with *p*H 6.0 to 6.8. Wood ashes serve the same purpose as lime besides adding a little potash. See Chapter 10.

When a bad soil must be used, various measures may be taken for its improvement. Growing and plowing in green-manure crops will help both very sandy and very heavy soils. Coal ashes that are not too coarse are useful for heavy soils. Manure, peat or muck, and sand may all be used to improve a small patch.

Equipment

A home garden enterprise can be very well carried on with a spade, a hoe, a rake, a trowel, and a little hand duster. The whole list can be bought in good quality for around $8.00. Since

the tools are good for five years or more and the garden can yield $50 to $100 worth of vegetables, it pays to get good tools—good metal, sturdy construction, and strong, smooth handles.

The level-back rake is preferred by many because it can be turned over and used for making a smooth-bottomed furrow of even depth for planting small seeds. Good metal is important

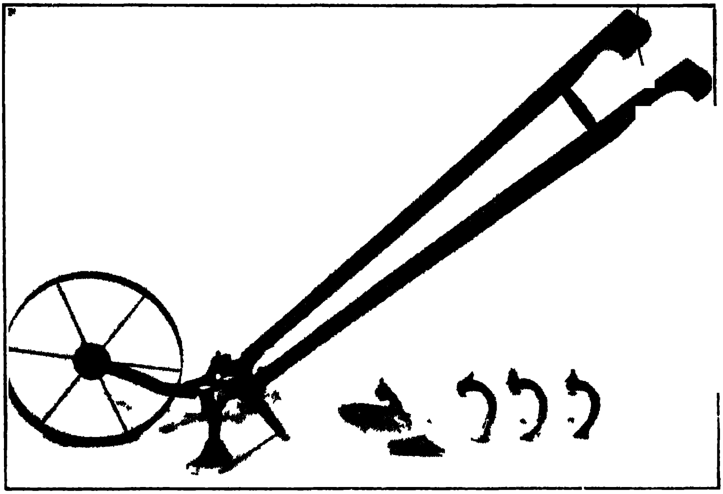


FIG. 25. Wheel hoe for home and commercial use. Low-wheel type shown here is better than high-wheel. For cultivation, blades are preferred to teeth as they destroy weeds and not roots of crop plants.

in the hoe, for it ought to be kept sharp with a file or grinding wheel. The bevel in grinding should be on the inside, not the outside, so that the hoe will bite into the soil and destroy weeds easily and thoroughly. The worst weakness in trowels is at the shank. Heavy, one-piece construction is desirable.

Wheel hoe. Probably the first addition to this set of tools would be a wheel hoe equipped with a pair of hoe blades for most of the cultivation, which should be shallow, and a set of teeth for loosening the soil. Many flimsy high-wheel implements are sold, but they are not seen on market gardens and that is a pretty good guide. The low-wheel type applies the power much more efficiently and directly and is more easily guided. With good makes, the whole implement is sturdy and tools are interchangeable.

Seed drill. A seed drill becomes valuable when a garden includes, say, a quarter acre of small-seeded crops or a half acre of coarser ones. In a small home garden, the trouble of adjusting drills to a proper seeding rate and then cleaning out left-over seed makes their use dubious.

The home garden needs a duster for control of insects and diseases. Dusting is much more convenient than spraying in small-scale operations. Some of the inexpensive hand dusters are very well made, but the very cheap flimsy ones are not likely to give satisfaction.

Tillage

On the farm the garden should be open for horse or tractor plowing. If a fence is necessary, arrange it so that it is movable at the ends. A good plowman can do an acceptable job around a 50 by 50 foot block, and a smaller piece can be plowed if there is turning ground at the ends.

Fall plowing is desirable in the north to permit early planting and to avoid delay by interference of other work. It is important if sod is to be turned under Furrows should be left unharrowed over winter. See page 194.

Harrowing follows spring plowing, using equipment and methods best adapted for the particular soil. For early plantings, a small plot of the fall-plowed land can be prepared with a wheel hoe or even with a small hand cultivator or hoe or rake, depending, of course, on the kind of soil.

Spading is not as big a job as it seems; an hour's work turns a surprisingly sizable block of soil, say 200 square feet. Manure or compost is applied first and, perhaps, fertilizer with it. Spading should be deep, usually 8 inches, but not cutting deeply into subsoil. It is better to take off a 4-inch furrow slice at a time than to take 8 inches; it is easier, makes a better job, and is not much slower. In turning the soil, the sod or surface should go to the bottom, and one should keep open a furrow of a spade width or so as he goes. If manure or refuse is heavy and coarse, rake it into the bottom of the furrow and cover it well.

Working soil when too wet is damaging, especially to heavier soils. Learn to recognize by the feel of the soil the degree of moisture that works well. A ball of soil shaped in the hand should not be sticky and should fall apart readily. Letting

heavy soil get too dry before plowing or before harrowing is about as bad as working it when too wet.

For cultivation and care of plants, see the proper chapters, both general and on the crops. Chemical weed control is thus far not very practical for the home garden.

Irrigation

Irrigation in the home garden yields rich dividends in yield, table quality, and full use of land. Water may be applied by any of the methods described in Chapter 12. It is better to water thoroughly at infrequent intervals than to sprinkle every day. A rough guide is to use the equivalent of an inch of rainfall each week when nature does not provide. This means 27,000 gallons per acre or 62 gallons per 100 square feet. Holding a nozzled hose is a slow method, and the gardener usually tires out before the job is done. Time and water are both wasted.

The hose may be allowed to run in a little furrow between the rows. Rotary sprinklers are not very manageable for small gardens as they leave unwatered corners. Small and efficient oscillating sprinklers are to be had at modest cost; these water a rectangle. Perforated aluminum pipe and perforated plastic hose are available. To estimate rate of flow, read the house meter or note the time required to fill a pail.

Insects and diseases

Many insect and disease enemies can be controlled in the home garden by the use of a single combination dust including rotenone and a fungicide such as copper or a carbamate. It pays to get a well-made hand duster of, say, 2-quart capacity costing now about $2.50 or $3.00. See Chapter 13 and the crop chapters.

Using the products

For full satisfaction from the garden, most vegetables must be harvested at the right stage of maturity. It is better to harvest and preserve or give away than to let products pass their best stage. Potatoes and root crops can remain in the soil for some time without serious harm, depending on climate and weather.

To gain full benefit from the vegetable garden, canning or

freezing and storing are necessary. Thus, the advantages are extended to every month of the year. See Chapter 14.

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See references in other chapters for special topics, as soils, seeds, plant growing, enemies, storage.

3

Vegetable Farm Management[1]

More farmers fail because of poor farm management than because of poor production.—G F WARREN.

The farm is to be thought of as a business enterprise in which it is necessary that income shall exceed expenditure by enough to maintain a good living

Measures of success. The measure of success in farming is usually viewed in terms of dollars, but other values are even more significant in the eyes of most farmers A choice of farming as an occupation cannot safely be based on the prospect of becoming wealthy or achieving great power. Tens of thousands of people regard farm life as good and are willing to yield somewhat of profit in return for its satisfactions.

PLANNING GOES HAND IN HAND WITH LABOR

It is not within the province of this book to go into detail on farm management; good books, bulletins, and courses of instruction are available.

Farm-management studies indicate that few farmers realize the importance of taking time from actual manual labor to study and plan. Real planning calls for careful analysis of factors, jotting them on paper, deciding the weight of each, and forming a plan of action in the light of all elements.

A plan should include: (1) financial plan; (2) cropping plan for the farm; (3) plan for maintaining fertility; (4) specific plans for the management of each crop; and (5) marketing plan.

Planning provides for the best distribution of labor and of income, and for the hazards of weather and market. It is worth while if for no other reason than to have equipment and supplies ready when wanted.

Foresight. Thinking and planning need to be done in advance. When the farmer comes out at seven in the morning, his mind should be made up about the day's work so that he can tell each man what he is to do and what materials and equipment he is to use. This commands confidence, respect, and cooperation.

Flexibility. Since the farmer deals with the sudden variables of nature, plans must often be changed; but changes are easier and safer after the various factors have been considered and a program has been drawn, especially if thought has been given to alternative plans. Then there is something definite to change.

LOCATION

Choice of location for growing vegetables must begin with a decision about what one wants to do. Some farmers are highly successful in each of the various types of vegetable-production enterprises—growing for local market, for shipment, for processing. Each type has its advantages and its disadvantages. Much depends upon the characteristics of the person. Roadside selling is not to be undertaken unless one likes to please people and is interested in handling details with precision. A great shipping enterprise is not to be undertaken unless one has the qualifications of a good business executive.

Regional location. In choosing the part of the country in which one wishes to grow vegetables, the principal considerations are climate, soil, and relation to market—the last including transportation. Growers in the warmer climates enjoy long growing seasons but they often encounter greater difficulties than northern gardeners from insects and diseases, from periods of cold weather or excessive rainfall. Winter crops grow slowly because the days are short. In much of the south, summer, not winter, is the time when vegetables do not grow well. In the north the season is shorter than in the south, but plants grow rapidly because days are longer and conditions in general are more uniformly favorable, even though sometimes marred by drouth, wet weather, or untimely frost. Thus advantages and disadvantages of the various regions tend to balance.

In most general climatic regions, a considerable range of soil

types is to be found, so that climate remains the major basis of choice of location.

Adequate transportation facilities, by rail, highway, or water, are essential. Greater distances involve higher costs, which are a first charge against gross returns. Availability of more than one carrier is desirable.

As industry becomes more evenly distributed throughout the country, opportunities for sales on local markets are constantly improving. These outlets are often neglected in regions of heavy production for shipment.

Points to be considered in choosing a farm

An outline on choosing the farm should include the following main headings:

1. Marketing facilities and outlets.
2. Transportation.
3. Climate.
4. Amount and usefulness of land.
5. Topography, erosion and flood danger, exposure and protection, drainage
6. Soil. See Chapter 10.
7. Labor supply.
8. Water supply.
9. Improvements, buildings, roads, equipment.
10. Community as a place to live and do business.
11. Cost and salability.

In a strange community, it is well to see the county agricultural agent, inquiring what he himself can tell and asking him to suggest whom to approach for wise and unbiased counsel. It is even better to live and work in a community for a time before buying.

CHOICE OF ENTERPRISES AND CROPS

Choice of location and choice of crops are bound to depend upon each other. Having selected a region, one may choose crops; having selected a type of vegetable farming, one may choose the location.

Diversification. In general, a reasonable degree of diversity in cropping and in planting times is still desirable or even neces-

sary. Diversification provides for reasonable spreading of risks of crop failure, of low prices, or of other marketing hazards; it also provides good distribution of costs, especially of labor, and, of returns. In the north a single crop such as cabbage may be grown in three or four plantings to sell from June to January. A crop succession of asparagus, peas, cabbage, tomatoes, and squash furnishes a good distribution of labor and of income. Risks may be spread between crops that are hardy and tender, as onions and tomatoes; between those that are drouth-resistant or not, as watermelons and lettuce; that make heavy or light labor demands, as process peas and sweet potatoes; that cater to staple or luxury classes of trade, as potatoes and muskmelons. The object is to offset each serious risk by an enterprise in which that risk is light.

Specialization. For many years the trend has been toward increasing specialization and away from the old market gardening with its wide variety of crops. It is increasingly necessary to produce in volume in order to reduce costs and to grow the crops for which conditions are especially favorable.

Points about crops. Some of the points to consider in choosing crops are:

1. Adaptation to local conditions: hardiness to unfavorable soil, temperature, and moisture conditions.
2. Susceptibility to diseases, insects, weeds.
3. Cost of labor and supplies.
4. Whether catering to staple or luxury demand.
5. Time required to reach maturity.
6. Maturity time in relation to market demand.

FARM LAYOUT AND CROPPING SYSTEM

In laying out fields, one must take into account:

1. Topography and soil characteristics.
2. Number of crops to be grown and quantity of each.
3. Plan for rotation of crops although schemes are much less definite on vegetable farms than on general farms.
4. Accessibility and convenience for working and especially for harvesting.

In general, fields should be reasonably alike in size and uniform in type of soil, so that suitable land for crops will be avail-

able each year of the adopted rotation plan. Fields may, of course, be subdivided at some stage in the rotation. Many farms have more than one rotation set.

Rotation plans may well keep a fourth to a half of the land in sod or soil-improvement crops each year.

Long rows, within limits, favor economy in operation Rows of uniform length are convenient for measuring, planning, accounting; for use of portable irrigation equipment; for proper loading of sprayers, dusters, and fertilizer spreaders; and for harvesting.

LABOR

Labor greatly affects the cost of producing and selling goods. Labor is the principal factor in the transformation of natural resources into consumer goods, whether aided by machinery or not.

Professor G. F. Warren, in his book *Farm Management*, said: "He who is to make by employing labor must direct it better than the average." Increasing costs of labor make this statement even more significant today. It is necessary to use every device, whether by equipment or by management, to increase the output of goods per man-hour of labor.

Much seasonal labor today comes from great distances. This migrant labor involves serious problems in achieving efficiency in operation, as well as contentment and welfare of workers. Some growers are very successful from both angles.

Size of enterprise is an important factor in making efficient use of labor possible. The proper size varies considerably, depending on the type of farm. Suitable size makes it possible to have help especially adapted for various kinds of work; it minimizes time lost in leaving one job and starting another; it justifies use of labor-saving equipment. An oversized enterprise may lose through cost of supervision and inability to keep everyone interested.

Working conditions. No general rules can be established for rates of pay and conditions of work. Local customs, fairness, and consideration for the interests of both the worker and the farmer must guide. Good help should be rewarded, and inefficient help should be replaced. Firm discipline is essential, and it is not resented if coupled with good humor and kindliness.

Many growers use young people from school on Saturdays and during the summer, especially during times of labor shortages. This is satisfactory for both parties if fairly managed. Handling such labor requires the qualities of a good scoutmaster or teacher —a liking for young people and the ability to keep them under control and to win their cooperation.

Efficiency of labor. Vegetable culture involves many small operations such as wielding a hoe, pulling weeds, transplanting, and picking tomatoes or beans. A second or so lost on each bean means heavy increase in cost per bushel. The grower must study the details of operations, learning to do things well and rapidly himself and then teaching others. At the same time, he should not forget that some variations in method are desirable among different people.

Supervision and responsibility. Constant alertness in supervision is necessary to see that the right thing is done at the right time. No matter how good one's help may be, things can easily be done wrong: plants set too deep, cover crops poorly plowed under, tomatoes picked too ripe or too green. Supervision is easy on the small farm, but it becomes an exacting task in larger operations.

Professor Warren advises keeping a memorandum of jobs to be done, so that the day's operations can be planned for minimum loss of time and effort in changing jobs. If it rains, the memo suggests some other task to be taken up at once.

The efficiency of labor depends upon having equipment and supplies ready. For indoor work, suitable floor arrangements, tables, and lighting are important. Working in tiresome positions or under poor light is inefficient. A brief break in tedious jobs is a useful aid. Radios installed in packing houses provide diversion and curb conversation. Overlong hours and a seven-day week lower efficiency and should be resorted to only in serious emergency.

It is hard to measure the efficiency of labor, partly because conditions differ widely. As the number of published account records increases, one can compare man-hours per acre of a crop for various farms. Even without such comparisons, one may note the work accomplished by different workers and may help others to reach a good standard without indulging in high-pressure methods.

COSTS, RETURNS, AND PROFITS

A business soundly conducted should pay all expenses of labor, materials, and services, and give a reasonable return for the operator and for the use of the capital invested. Profit is the operator's reward for conducting the business. Profit plus wage for work performed is his "living" in lieu of the wage or salary he would receive if employed.

In calculating costs and returns, decision as to just what items shall be counted as deductions from gross returns and what shall be counted as cost is rather arbitrary. Grower-shippers often record as returns the gross sale value at distant market, less "freight, cartage, and commission"—the cost of transportation and selling. This is comparable to an F.O.B. price Market gardeners are likely to consider costs of truck, stall rental on market, and time used in selling as operating costs. Sometimes crops like cannery beans are sold unharvested and the buyer does the rest. The point is to be sure one understands just what is included in such terms as costs, gross returns, and profit, and whether comparisons are made within the farm or with other farms.

The "man work unit" is a useful measure for analysis of operations. This is the amount of work accomplished by one man in a 10-hour day at an average rate. In New York, the data shown in Table 3.1 have been published. Similarly, costs of operating tractors, trucks, and other items of equipment have been worked out in various states.

TABLE 3.1. WORK UNITS PER CROP ACRE *

Beans for cannery	4	Potatoes	8
Beans for market	30	Tomatoes for cannery	14
Cabbage, late	9	Hay	1
Carrots, bunched	45	Corn silage	3.5
Carrots, topped	25	Dairy cow (per animal per year)	15
Celery, early	45		
Peas for cannery	2		

* Hart, Bond, and Cunningham, *Farm Management and Marketing*, p. 70.

Information of this sort is not to be taken as gospel; conditions vary too widely; but it is helpful in judging the efficiency

of one's own operations. If cabbage requires 200 hours of labor per acre on a New York farm, there is something to look into, for the average in New York is 90 hours.

Cost accounts must include interest on capital, labor costs, depreciation, upkeep, and operating cost of equipment, and supplies like seed, fertilizers, spray materials, and packages.

It is common to separate costs up to harvest time from costs thereafter. This is good practice since costs up to harvest vary but little with yield, whereas harvesting and marketing costs follow very closely the quantity harvested.

See cost account for tomatoes, Chapter 18, as an example of a crop account.

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4

Marketing Vegetables

—and they sat down and gathered the good into vessels, but the bad they cast away.—*Matt.* 13.48.

A good marketing program has four objectives: (1) to carry the produce through to the consumer with quality unimpaired; (2) to present it in attractive and readily salable form; (3) to keep the costs of the various steps to a minimum; (4) to get a good price.

By these means, the grower aims to realize a suitable net return from his effort.

In this book the term marketing includes all the steps from the time produce is ready to harvest until it is in the hands of the consumer.

QUALITY

Quality comes first

Much attention is given, and rightly, to the various problems and processes involved in marketing. But suppose you visit a city market where a salesman is trying to move the perishable produce for the topmost nickel of price. You ask him which is the better package for bunch carrots, the bushel basket or the Los Angeles lettuce crate. That is a good question, but he will probably answer, "It depends on how good the carrots are." And he is right. Quality is more important than package or anything else; it is the paramount requisite for success in marketing.

The many recommendations for care in harvesting, for cleaning and sorting and packaging, and for protection from heat and drying are all of value so far as they help to conserve the quality that was present in the produce when it was harvested. If they do not serve these or other useful ends, they are not to be recommended.

Western Grower and Shipper and Pennsylvania State College

FIG. 4.1 The consumer is the final arbiter in marketing. Retail selling is an essential step in the process. A great food market in Los Angeles and a farmer market in Pennsylvania.

Much care is required to discriminate between really useful advances in marketing and innovations that merely afford talking points for salesmen or give the impression, without foundation, of a better job of marketing. We need better practices, we do not need mere frills and furbelows.

What quality is

We all talk very freely about quality, but we seldom stop to consider what quality is, what factors impair it, and how it can be conserved. There is very little we can do to improve upon the quality of the harvested product.

Quality is made up of a great many characteristics, some external and some internal, some physical and some chemical.

1. **Appearance.** When we judge quality in produce, our first impressions are those of sight. We look for shape, color, and freedom from blemishes and dirt. Defects which cause waste in preparation are serious.

2. **Texture.** We are interested in whether vegetables are hard or soft, granular or smooth, stringy and fibrous or free of fiber, crisp or flabby. Illustrations of undesirable texture characters are stringiness in celery and beans, toughness in kernels of sweet corn, hardness in peas, and wilting in lettuce. Illustrations of desirable texture characters are crispness in cucumbers, mealiness in potatoes, and juiciness in melons. These properties depend on the stage of maturity, inherited characters, cultural conditions, and moisture.

3. **Flavor** is a combination of taste and odor. If you doubt this, pinch your nose or stop it with cotton when you sample an apple or a muskmelon. *Taste* is recognized in the mouth and depends on compounds that are soluble. *Odor* is sensed by the nose and depends upon compounds that are volatile or vaporized It is claimed that all tastes are combinations of sweet, sour, bitter, and salt. Some hold likewise that there are just four primary odors: sweet, sour, burnt or caramel, and caprylic or "goaty." Other mouth sensations are due not to taste but to touch, like the pungency of hot peppers and the astringency or "puckeryness" of unripe persimmons. Tastes and odors are traceable to chemical compounds often present in such small amounts as to defy analysis. Some of these are essential or volatile oils, as in mint; others may be traced to various kinds of chemical compounds such as acids, proteins, and glucosides

Much basic research is in progress, exploring the nature of our quality judgments and the conditions that govern them.

4. **Nutritive value,** discussed in Chapter 1.

CONSERVING QUALITY

The following paragraphs are concerned with the things that can be done to keep harvest quality unimpaired until the goods reach the housewife.

Too many farmers assume, rather thoughtlessly, that their responsibility in marketing is at an end when the produce leaves their hands. On the contrary, the quality of the goods de-

livered today determines in large degree whether or not the farmer can sell next week and what price he will realize. Mrs. City Dweller finds the beets shriveled. She does not buy them next time. Neither does the retailer or the jobber buy, and the shipping point dealer says that the market is slow.

Harvest carefully and at the right time.

When to harvest. Some products such as summer-maturing potatoes allow considerable leeway in harvesting. Others, like sweet corn and peas, pass the stage of proper maturity very quickly. Some growers cut asparagus twice a day when the weather is hot. General rules cannot be laid down, but the aim should be to take the product at the stage of maturity that will get it to the housewife in prime condition for table use. For products like muskmelons, maturing on the plant yields better quality than ripening after harvest. High temperature hastens maturity of most growing things and necessitates more frequent harvest. Delay in harvesting may increase the total yield very materially, but it also may allow opportunity for heavy losses from insects, disease, sun-scald, rain, frost, premature seeding, and the like, as well as for decline in quality. Peas for processing gain greatly in weight but become hard and lose sweetness if not harvested at the proper time.

Frequent pickings may make for better quality, but against this must be balanced the increased labor cost. Strains of seed bred for uniform maturity help to solve this problem. It is better to have two smaller plantings of early cabbage, cutting each twice, than to face the necessity of going over a much larger, unevenly maturing patch three or four times.

Time of day when harvesting is done has an important bearing on the temperature of the product, which in turn has much to do with its keeping. Many harvest sweet corn between midnight and dawn. Some products are likely to be slightly wilted at mid-day and after. This may impair quality as with snap beans or it may safeguard against breakage and damage as with spinach or lettuce.

Prevention of mechanical injury is another factor in harvesting that deserves utmost care. Breakage of tips of asparagus, bruising of cabbage, cutting the skin of winter squash are all serious. Digger injury to potatoes takes a toll of thousands of

dollars yearly. Damage not apparent at the time may become serious later. It is very easy for the "boss" himself to become careless; eternal vigilance is necessary in supervising help.

Pick your own. With increasing labor cost, some growers allow customers to pick their own tomatoes, peas, or beans at bargain prices, often after the first harvest or two has been made.

Trimming

Good practice in trimming vegetables for market calls for the removal of damaged, dead, or discolored parts to save transportation and handling of inedible material as well as to improve

Boggs Manufacturing Company

FIG. 42. Markets demand clean goods Unbrushed and brushed potatoes.

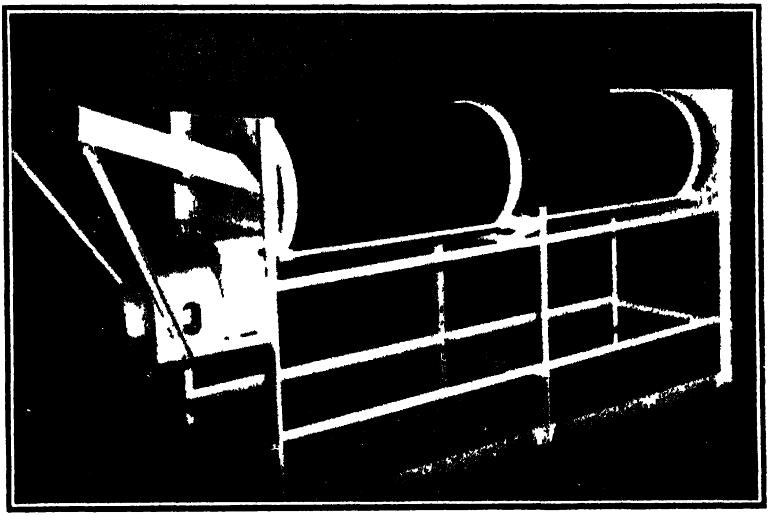
the appearance of the product. Celery should be trimmed closely and packed in crates that fully enclose the tops. On the other hand, the outer leaves of lettuce, cauliflower, and cabbage afford needed protection for the product.

Markets demand clean goods

The housewife is increasingly intolerant of soil or dirt on the things that she buys. It both impairs the appearance of the product and soils the clothes and hands of the purchaser—a point of increasing importance when so much buying is through self-service stores. It is the occasion for disgust and inconvenience in the modern kitchen, which is as clean as great-grandmother's parlor.

Keep produce clean. Produce should be kept as clean as possible during harvesting; special care is required after rains and on dewy mornings. Field crates and baskets help protect the produce from dirt.

Washing vegetables. Mechanical equipment is thorough and rapid, but judgment should be exercised to avoid higher investment or more elaborate set-up than is justified by the quantities



American Specialty Co.

Fig. 4.3 Tumbler washer for roots. Fed at one end, it discharges at the other.

handled or the prices realized. On the other hand, simple small-scale equipment that can be operated with few workers greatly speeds up operations over clumsy hand methods. See Figs. 4.3, 4.4, and 4.5.

Large tubs and hand brushing are common among market gardeners. A small brush washer is effective for bunch goods. Some employ a high-pressure spray head or a special gun-type nozzle such as is common for washing automobiles. Another method is to pile bunch vegetables like cordwood and wash with a hose. Care is needed to see that dirt is not washed into the tops and left there.

Increasing use is being made, especially in central packing houses, of washers consisting of a conveyor belt carrying the

Fig 44. Students at University of Florida gain experience in washing vegetables.

products through a chamber in which they are washed by spray from top and bottom. See Fig. 25 3. This plan is almost universal for celery houses A small washer of this type is now on the market at moderate cost Root crops with tops off are washed in revolving cylinders of various types, usually fed continuously at one end and discharged at the other.

Advantages of washing. Washing not only removes dirt but also freshens the produce, giving it an opportunity to absorb water and restoring wilted tissues. It is likewise of value in removing poisonous spray and dust residues.

Wetting produce sometimes encourages the ravages of disease, but this effect is usually counteracted if goods are immediately cooled and kept cool. There are some exceptions to this as certain organisms thrive at low temperature in the presence of moisture.

Brushing. Potatoes, cucumbers, and muskmelons are often cleaned by brushing or wiping dry rather than washing. Several forms of machines are available for this.

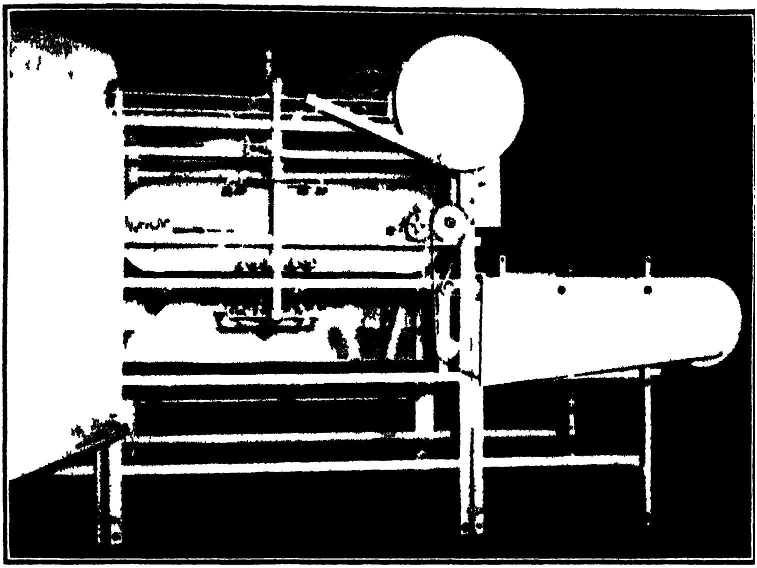


Fig. 45 Washer for bunch vegetables which are sprayed from above and below as they pass along a conveyor belt Side cover is open to show construction

SORTING OR GRADING[12]

Nature does not make vegetables all alike They differ in many respects as the result of differences in heredity and environment, that is, differences in parentage, in soil, in the weather that has surrounded them, in the insects and diseases that have attacked them, and in the actual handling by the farmer and his help

The trend in vegetable marketing is toward separation of products into classes, called Fancy, No 1, No 2, and Cull, or by some other series of names This is sorting for *grade* Products may also be separated according to *size* Tomatoes are designated 6 by 6, 6 by 7, or 7 by 7, according to the number of rows each way in a layer in the lug box Sorting is also based on *ripeness, color, quality, blemishes,* and other characteristics which make a difference in the prices people are willing to pay for the goods.

Most people speak about *grading* vegetables, fruits, or other farm products, and they probably will continue to do so It

would seem better to keep "sorting" as a general term and to apply "grading" to only one kind of sorting—sorting for grade.

When sorting and packing are well done the seller is as willing to show the bottom of a package as the top.

Sorting is often a simple job. Some people think that sorting or grading involves the elaborate packing-house set-up, the complicated standards, and the great retinue of labor found at the big shipping centers. As a matter of fact, practically everyone does some sorting. The farmer who harvests carrots in the field, leaving the poor ones on the ground and bunching the good ones, is actually sorting. The question is not *whether* to sort but *on what basis* to sort and how to do the work. One should adopt a sensible, practical, profitable program, simple or complex, to fit his own conditions. A "super" program is likely to cost too much and to fail.

Advantages of sorting

Some of the advantages that may or may not accrue from sorting are:

1. Avoidance of loss in selling price that usually results from the presence of substandard specimens.

2. Avoidance of heavy marketing costs on goods that are not of high enough quality to bring a price sufficient to pay those costs, notably packaging and transportation.

3. The furnishing of a common language between buyer and seller. Buying by inspection on public market is a costly and troublesome way to do business. Grocers prefer to give an order and to be assured of the quality they want. This requires a language that both parties understand. It may take the form of a definite designation of grade, size, and maturity: "Send me 10 lugs of tomatoes, 6 by 6, U. S. No. 1, half-ripe but not soft; Tiger brand if you have them." That common language is based on sorting.

4. Relief of oversupply by removal of low-grade goods from competition in selling.

5. Avoidance of damage to good specimens through contact with bad, especially diseased, ones.

How gains are realized

Just how far and in what ways and under what circumstances these five arguments are effective cannot be set forth in any

clear-cut fashion. Too many factors are involved, some favorable to sorting, some unfavorable. So, as always, a balance must be struck between benefits realized and their cost. The advantages may take three forms: (1) actual dollars in increased prices; (2) easier selling; and (3) greater volume of sales. Building a reputation for quality and good service is an important factor. It must be remembered that in many situations returns will not justify any sorting program that goes beyond leaving culls in the field.

Program

The plan adopted will depend upon several considerations.

1. **Quantity and quality of the crop being grown.** An elaborate set-up is not justified if the volume handled is small. If the quality is low, little handling can be done with profit. The percentage of U. S. No. 1 or higher quality must be sufficient to justify selling under more than one grade. Discarding of culls in the field is a widespread practice feasible with any crop.

2. **The standard for sorting.** It is necessary to decide just how poor a potato must be to be left in the field, or just where the line should be drawn between the No. 1 and the No. 2 grade.

United States Standards[12] afford a first-rate starting point in planning a system of sorting for grade. Some growers find it is desirable to pack a better grade than U. S. No. 1, designating it "Fancy"; others prefer to modify the standard in some respect to fit their own circumstances. If the standard is lowered, the products may not be labeled U. S. No. 1. Other standards are often decided upon and followed.

Copies of United States Standards for grade should be procured from the U. S. Department of Agriculture and studied carefully, especially to understand the basic distinctions such as "free from," "free from damage by," and "free from serious damage by." Tolerances under United States Standards are liberal. It is well not to override them if goods are to be labeled by United States grade.

It is well to write down the description of each grade so that the standard may be kept constant. Sizing cards, drawings, or pictures help to hold the standard.

3. **Costs** of equipment, operation, and labor in relation to probable increase in returns to be realized through the adopted program.

The return received for U. S. No. 1 grade plus the return received for U. S. No. 2 grade must exceed the return that could be realized for unsorted goods by an amount sufficient to pay the extra cost involved in sorting.

4. **Range of prices** that are likely to be realized for the crop. This depends upon the size of the possible market outlets and the class of trade that can be reached. One does not have to serve any great proportion of the trade of a large city to be successful with a de luxe line. On the other hand, it is usually better to reach a large number of good buyers with a first-class but not extra-fancy standard. Other growers find it profitable to cater with a good commercial grade to the masses who have little to spend.

EQUIPMENT AND METHODS FOR HANDLING VEGETABLES

Sorting to the extent of leaving culls or culls and seconds in the field requires no special equipment and no increase in labor requirement.

Set-ups for sorting are usually combined with those for cleaning and packing.

It is possible to make a field pack based on two definite classes of goods, either two grades, two sizes, or two maturities. In Salinas, California, field carrots are tied as pulled. The workers size uniformly within each bunch, but successive bunches may contain specimens of different sizes and thus each crate will include various sizes to suit the ideas of different housewives. This leaves washing and packing to be done at the central plant, many of which are large and elaborate.

Field versus central handling. The desirability of sorting and packing in the field as compared with central packing depends on many circumstances, including the nature of the crop. In general, central packing gives (1) greater efficiency in labor, (2) better supervision, and (3) a more uniform and more salable product. Central packing does not necessarily require an elaborate plant. A simple sorting table with stands for packing may be set up at the edge of the field. See Fig. 18.4. If it is desirable to use mechanical washers, conveyors, and box-making and nailing machines, a central shed for the whole farm or for a number of farms is desirable.

Undue handling, lifting, and setting down are to be avoided Pallets or skids should be more generally used, even by small operators since simple jacks are available High labor costs have necessitated increased use of conveyors, with or without power, hoists, and loaders

Various forms of 'packing sheds on wheels" have been devised, as for celery and sweet corn in Florida Illustrations in various crop chapters show several set-ups from simple to complex

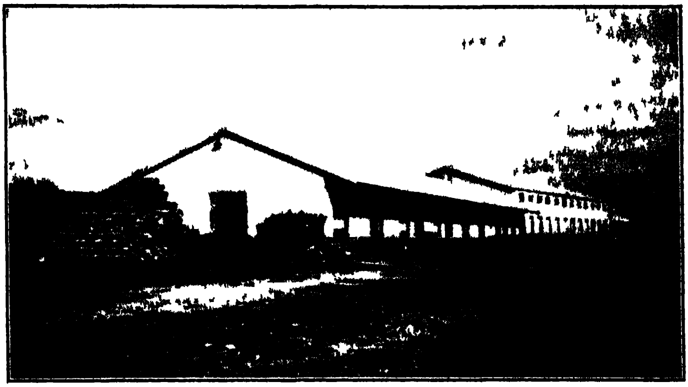


FIG. 46 Packing arrangements vary widely from simple field operations to small sheds and up to vast arrays of sheds with elaborate equipment for many crops See also lettuce packing house pictures, Figs 263 to 268

Cabbage, spinach, and sweet potatoes are seldom shed packed, the last because of the serious damage through even slight bruising Tomatoes and asparagus are very commonly shed packed Practice varies widely with the other vegetables, central packing being generally on the gain

Mechanical sorting devices, chiefly for *sizing*, utilize a good many different principles Some consist of broad belts with holes of successive sizes Some have pairs of belts or slots between bars that are spaced farther apart as the goods pass along One make of sizer operates by balanced weights This is good for tomatoes with their irregular shape

The principal aid available for sorting for *maturity* and *grade* is a conveyor belt which makes it convenient for workers to transfer specimens to bins or to other conveyors

Inspection. To be effective any plan of sorting must be backed by adequate inspection. See Fig 47. The grower may simply

keep an eye on the job to see that the standard which he has set in his mind or on paper is maintained. A government shipping point inspector may be called in to inspect the goods and to issue a certificate for each car or truck load.

FIG. 47. Federal-state inspector, J F Akins, checks cauliflower as it is loaded in western Maryland Note refrigerator car construction and wire-bound crates.

At the receiving end, inspection services are available to check quality, condition, and grade on arrival. These services may be governmental or private or under the auspices of the carriers who are concerned with claims involving damage in transit.

PACKAGING

Packaging practice ranges all the way from shipping watermelons in bulk in carloads and handling bunch carrots in armfuls by truck, to selling tomatoes and mushrooms in small consumer cartons with windows of cellulose film The trend is definitely in the direction of small consumer packages

Cornell University

Packaging has almost wholly replaced bulk handling

FIG 4 8 No packaging Vegetables exposed to dirt and dust subject to severe wilting apparent in the carrot tops

FIG 4 9 Nondescript packages much overloaded badly packed with little protection for the goods Compare Fig 4 10

Points to consider in planning for packaging

1. A good package is designed to deliver the contents conveniently and cheaply with quality unimpaired. To this end there must be adequate strength, absence of damaging corners

U S Signal Corps

FIG 4 10 Vegetables well packed in good containers

or surfaces, and sufficient protection against drying out and mechanical injury.

2. The good package is adapted to the kind of crop it is to carry, as regards size, shape, type of construction, material, and provision for ventilation or protection as needed.

3. The good package is well adapted for convenient and economical packing and handling.

4. The good package enhances salability of the goods, being

itself attractive, displaying label and contents to advantage, and being of suitable size as a unit of sale.

5. The good package is well adapted for transport, loading, and stacking, with security and economy of space. Most baskets are open to criticism on this score. Minimum weight, consistent with other objectives, is desirable.

6. Other things being equal, the package should be standard. This need not deter a grower or shipper or association from adopting a new package provided that the advantages, including distinctiveness, are decisive.

Kinds of packages

Wood is the most widely used of all package materials. Packaging takes 10 to 15% of all our lumber production.

Sawed lumber is cut and nailed into boxes and crates. Some have solid board ends, as the tomato lug Some have framed ends, as the western lettuce crate. A few have corner posts, as the western muskmelon crate.

Veneer is made by steaming logs and cutting thin sheets with a fixed blade mounted in a lathe. Thicknesses run from 1/5 to 1/64 inch. Handles and hoops are usually 3/32 to 1/8 inch thick; stave and braid material is thinner, and slats to be stitched together for crates are thicker. Veneer must be sorted for defects, and the quality of packages depends largely upon how well this is done. Huge machines shape and stitch round baskets from mats which are made up by hand.

Veneer is much used for crates and boxes. Many containers are of wire-bound veneer, such as the Howard celery crate and the Bruce box, in which Florida oranges are often shipped and which is widely re-used for vegetables for local sale.

Paper-board in various forms is increasingly used for containers for vegetables. Most of the baskets for hothouse tomatoes are now of corrugated board. There has been considerable experimentation with cartons of various sorts for potatoes, with some success, but bags still prevail even for consumer packs. Paper-board is now widely used for western dry-pack lettuce, vacuum-cooled and shipped without ice. Master containers for consumer package are commonly of paper-board. Manufacturers are constantly devising containers for vegetables, and

some of them are likely to prove successful, provided that costs can be brought to reasonable levels.

Bags may be made of many materials as follows:

1. *Burlap* is imported from Asia. This material is normally cheap, strong, but somewhat lacking in attractive finish, and it does not carry printing as effectively as other materials.

2. *Cotton* is less strong than burlap, but more attractive and more printable.

3. *Paper* of a strong type called kraft (see page 59) is used, one ply or more, for bags from small ones to those of 50-pound capacity. It may be partially waterproofed. Small bags are made of many forms of paper. Paper is attractive, inexpensive, and takes printing well.

4. *Paper twine,* water resistant and strong, is woven into bags which are attractive in appearance and permit visibility, but labeling and printing present something of a problem.

5. *Cellulose, rubber, and other films* are used for small bags for consumer delivery, increasingly for soup and salad mixtures of shredded or diced vegetables, and for many products such as dried peas and beans. These materials offer adequate strength and high visibility, and they are easily printable. Grades of material must be chosen with care to insure proper conditions of moisture.

Prepackaging.[21] There has been marked development in packages which will carry small quantities of vegetables to the housewife's kitchen, without rehandling. The development of self-service stores has given a great impetus to consumer packaging of produce.

In general such packaging accomplishes the following:

1. Avoids much of the labor cost and waste which the retailer must meet, and which are incident to weighing, trimming, sorting, wrapping or bagging, and handling.

2. Packages carry brand names and advertising to the housewife, helping to build a reputation for goods of high quality, and giving effect to other advertising.

3. Consumer packaging affords protection against evaporation, dust and dirt, and handling by customers.

It is necessary to distinguish between actual improvement in packaging service and mere fancy trimming. Most prepackaging or consumer packaging is highly organized and uses elabo-

rate equipment and often cold-storage facilities. Thus the plant must operate most of the year so the job is often done by concerns specializing in this business. On the other hand, some growers find it profitable to prepack their goods on a seasonal basis, using a simple set-up.

Film bags are commonly used for spinach, salad mix, soup mix, and carrots and other root crops. Tomatoes, celery, sweet corn, and some other vegetables are laid on paper-board trays and overwrapped by machine with some type of film.

A major problem is to keep costs in line with what the consumer is willing to pay. Under prosperous conditions this is readily achieved. Berries and mushrooms have been prepackaged for years.

Paper sheets of various sorts play an important part in the marketing of vegetables. Common uses of paper are: (1) as wraps for celery, asparagus, and tomatoes; (2) as liners for crates and baskets of lettuce, carrots, and beets, and as top sheets for baskets of topped carrots and beets and occasionally for other commodities.

Paper may offer some or all of the following advantages:

1. Protection from dirt, dust, and infection. On the other hand, by keeping humidity high it may favor disease.

2. Retarding of evaporation and wilting.

3. Protection against unfavorable temperatures, against heat from without, and against freezing. It may also retard cooling, a disadvantage.

4. Provision of attractive "dress-up"; carrying of brand name and advertising to retailer and consumer. It also affords a good means of carrying recipes and suggestions for use.

As with other advanced methods, cost is a limitation. The difficulties connected with disease and retarding of cooling may be counteracted by proper precooling and refrigeration.

Kraft paper. Most of the paper used in marketing vegetables is called "kraft," a sulfate stock of great strength. Common brown paper bags of the grocery stores are of kraft. It is used in its original state or bleached. Kraft paper is often waxed and it may be parchmentized, a treatment with sulfuric acid which greatly increases its wet strength. Other treatments have similar effects in varying degrees. The white parchment paper used for

celery wraps and for some other purposes is a clean sulfite stock, treated with sulfuric acid.

Waxing

Experiments [9] have shown that water loss from vegetables can be reduced and their appearance can be enhanced by applying wax to the surface. Canadian rutabagas have for some years been given a coat of paraffin by dipping. The newer development consists in preparation of a water emulsion or a hydrocarbon solution of one or more waxes to be applied by dipping or spraying or as a foam. Topped carrots and other roots, cucumbers, tomatoes, and peppers are among the vegetables with which the treatment has been found advantageous.

Packing

More damage to vegetables is caused by loose packing than by too tight packing. Goods that move about in the container are much more subject to bruising and scarring than those held firmly in place. Security is a prime consideration.

Vegetables should be so packed as to give a good finish to the package. This means orderly arrangement, smooth surface, and, usually, a reasonable bulge or arch. A good finish does not mean putting the best on top and the worst below. A business man wants to continue to sell to the same people. Deception is a very poor way to accomplish this end.

The bulge pack. See Fig. 26.8b. *Slightly* overfilling the package is desirable for display and to insure a tight pack on arrival at market even though a little shrinkage may have occurred. The bulge idea is greatly overdone, becoming a serious abuse. Buyers may insist on a high bulge so that they may get extra goods. By the same token the seller is robbed. The housewife does not get any more than she pays for. High bulge also subjects the goods to unnecessary bruising and damage which may deprive the buyer of much that he thinks he is gaining.

LABELING

Producer and dealer both like to have the housewife ask for more. She cannot do so without some means of identifying the

product. So labeling is a practice of long standing, tracing back to the marks of ancient guilds and craftsmen.

Labeling may be accomplished in several ways:

1. Printing directly on wood or paper-board of container.
2. Pasting a printed label on the package
3. Wrapping with printed material or using printed bags.

Good labeling depends upon both color and design. One good color with striking design is more effective than many of the splashy three-color jobs that are so common and also expensive.

Much labeling goes no further than the jobber or retailer. The label of Ivory Soap or Shredded Wheat goes through to the housewife.

FACTORS GOVERNING DETERIORATION

Changes in quality are traceable to many physical, chemical, and biological processes. Important among these are evaporation of moisture; oxidation including respiration (page 96); destructive work of organisms, chiefly fungi and bacteria, vaporizing and escape of volatile materials, other chemical changes; growth and breakdown of materials and tissues.

Many factors affect the deterioration of vegetables after harvest. Most important of these are:

1. Temperature
2. Humidity
3. Diseases and insects

Temperature

Mrs. Alderson drives up to Walter Conrow's roadside stand and reports that the sweet corn she bought yesterday afternoon and had for supper was not as sweet as usual. Mr. Conrow does not understand how it happened, but, as he gets another dozen ears ready (no charge, of course), he tells her that someone may have given her a dozen out of a basket that was a day old. As the weather had been pretty warm, he says, "You know that with an average temperature of 85° sweet corn loses half its sugar in 24 hours. That is why I am so particular to pull sweet corn for the stand twice a day. I hope this dozen turns out better."

Mr. Conrow had science as well as the testimony of taste behind him. Experiments made by holding sweet corn at different

temperatures, analyzing chemically for sugar before and after, have shown just how rapidly sugar disappears at various temperatures.

Chemists use a principle called van't Hoff's law which says that the rate of a chemical reaction is approximately doubled for each 10° C. or 18° F. rise in temperature. So the disappearance of sugar, being a chemical process, goes on about twice as fast at 85° F. as at 67° F., and half as fast at 85° F. as at 103° F. See Chapter 7 for fuller discussion, also page 265.

Now, there are limits to the application of this law, but rise in temperature does hasten chemical changes, the evaporation of moisture, and the growth of decay-causing bacteria and fungi in the produce. After produce is harvested most of the changes lead downward and not upward; the goods get worse and not better. Thus, in general, it is best to keep products cool to retain high quality. One of the processes speeded up by rise in temperature is respiration, which itself releases heat in somewhat the same way as the burning of coal. This in turn speeds up the processes we have just mentioned. A truck load of sweet corn in bags will become very hot overnight just like corn in a silo or fresh hay in a mow. See Chapter 7 for respiration, Chapter 14 for temperature of storage.

There are several ways to control temperature of products as they pass from field to kitchen.

1. **Harvest when things are cool** early in the morning rather than at mid-day or later. This is not always feasible.

2. **Precool.** There are various methods of precooling, all rather costly but, for some products, very necessary. Four methods of precooling are as follows:

(*a*) *Storing in a cold room, or car or truck,* refrigerated with ice or by machine, is a slow method, requiring 24 to 48 hours for most products.

(*b*) *Dipping in very cold water* (*hydrocooling*) is much more rapid. A chlorine disinfectant is sometimes used in the cooling water (*stericooling*). Peas may be cooled in a few seconds; other vegetables, in proportion to the size of unit and penetration of water. The method is commonly objected to on the ground that the produce will mold or decay if wet. This is likely to be true if the temperature is allowed to rise after the precooling; otherwise not. Moreover, water remaining after

immersion is likely to be absorbed in a short time by the tissues themselves.

(c) *Packing ice with the goods* is an effective method of cooling produce and keeping it cool. See Figs. 26.8a and 26.9.

(d) *Vacuum cooling* is a more recent development extensively used for lettuce. It eliminates package icing. Goods are packed and placed in a chamber under high vacuum. This occasions very rapid evaporation * of water from the goods, sufficient to dispose of field heat but not enough to cause serious wilting. For a summary of this topic refer to *Western Grower and Shipper*, Nov. 23, 1952, for an article by Friedman, "Vacuum Cooling of Fresh Vegetables and Fruits."

3. **Keep produce cold.** After produce has been adequately chilled, it is kept cold by storing in refrigerated rooms, by shipping in refrigerated cars and trucks, by use of refrigerated cases in stores, and by means of the household refrigerator.

It is easy to be led astray in cooling produce. It is necessary to check carefully to see that the inside of the goods is actually cooled to the proper temperature and that the temperature remains low. Oherwise little advantage is gained.

Refrigeration checks evaporation and shriveling as well as other forms of deterioration.

Humidity

Evaporation or drying out is a major form of deterioration in vegetables. It causes wilting, shriveling, and loss of weight.

Rate of water loss depends upon several factors:

1. The kind of vegetable. Leafy vegetables with much exposed surface like spinach lose water rapidly. Others with a waxy surface such as watermelons lose water slowly.

2. Low moisture content of the atmosphere or low relative humidity increases the rate of evaporation. See page 266.

3. Air movement or wind removes moist air near the surface of the vegetables and replaces it with dry air.

4. High temperature increases the capacity of air for water

* Evaporation of one pound of water takes 970 B.t.u. of heat or enough to reduce the temperature of 24 pounds of produce by 40° F. A B.t.u. is the amount of heat required to raise the temperature of a pound of water 1° F.

vapor, and by reducing the surface tension of the moisture in the vegetables it speeds evaporation.

Moisture loss is controlled by keeping goods in an atmosphere of low temperature and high humidity. This is automatically adjusted if a storage room is full of produce and seldom opened. In smaller cold-storage rooms in stores or wholesale houses, special mechanical control may be necessary, or water may be sprinkled to keep the air humid and the goods moist. On display stands, spray heads are effective with certain kinds of vegetables.

Diseases and insects

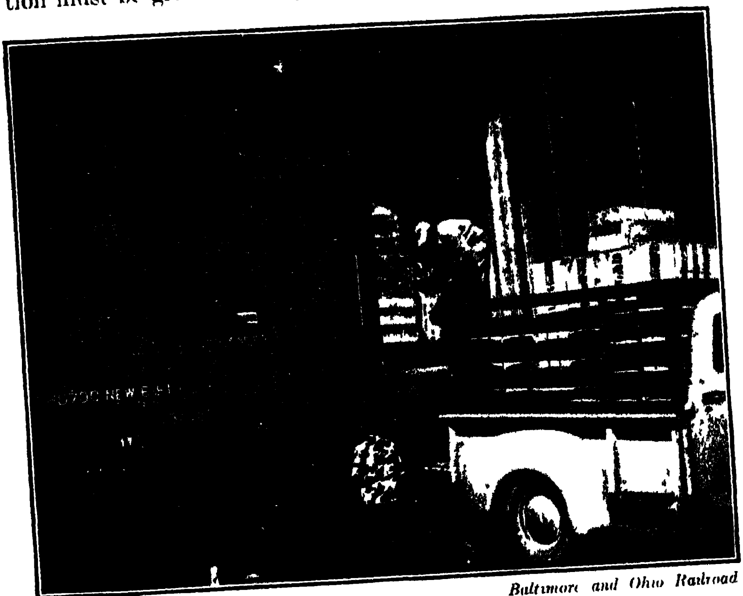
Injury from diseases and insects is the third most important cause of deterioration of vegetables during marketing, diseases being the more common and serious. In general, high temperature and high humidity favor disease damage, but there are exceptions, and it is necessary to recognize the diseases and to know their characteristics. A series of U. S. Department of Agriculture publications, "Market Diseases of Vegetables," is available.[11]

TRANSPORTATION

Transportation has become increasingly important in the vegetable business as years have gone on. The first car-lot movement was in 1855, and refrigerated cars appeared about 1870. Today thousands of loaded cars travel from coast to coast, mostly eastward, and from lakes to gulf, and vice versa. During the present century motor-truck transportation has become increasingly important in the movement of perishable vegetables. Water transport has been used to greater or less extent at various times. Air transport [23] is employed on a limited scale.

Rail versus truck. The railroads possess unassailable advantages in moving perishable produce in large quantity for *long distances*. It would take 80 to 150 great trucks, with two men for each truck, to move a trainload of vegetables. For *local movement*, the truck is indispensable. Where the dividing line is to be found is a matter of service and costs. At distances of 200 to 800 miles, the competition between the two is constant and keen. The railroads have excellent refrigeration facilities, and their terminals are generally good. Trucks can pick up goods at the field or packing house and deliver them at the store

door, but many of our markets were built before the day of motor transport, and congestion and delays are often serious. Refrigeration of trucks is improving. Railroads have shortened their delivery times. Constant adjustment between the two is going on. In making a choice in any particular case, careful consideration must be given to many factors.



Baltimore and Ohio Railroad

Fig. 4 11 Small open trucks take care of local movement Farmer transfers goods to out-of-town dealer

Load securely. In all transportation, security in loading is important. In car or truck a comparatively light container will serve provided that there is no shifting or movement. In railroad cars, special systems of stripping and bracing are used to prevent movement of the load. The railroads insist upon good practice in this respect as well as in specifications of containers so that losses to shippers and damage claims against the companies may be kept at a minimum.

Refrigerator cars are available practically everywhere. Both cars and service are well standardized. The cars are carefully constructed to resist water, as package and top icing keep them thoroughly wet. Many experiments have failed thus far to

render mechanical refrigeration practical for rail cars, though it is used to some extent on trucks The ice is renewed at stations along the road "Reefer" trains make 60 miles an hour at times,

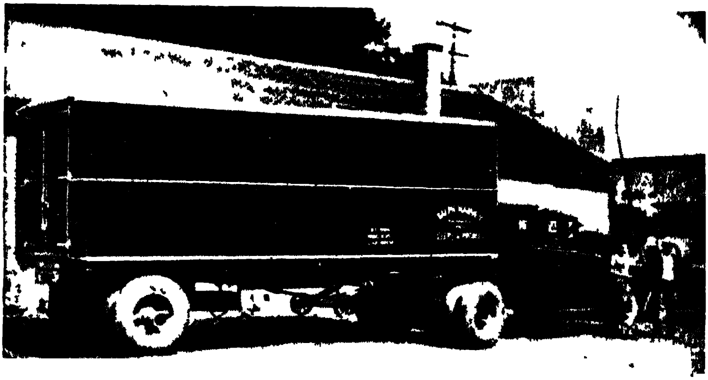


FIG 4 12 Refrigerated trucks handle produce for medium distances

but they still take eight days to get across the country. Bunker ice is supplemented by top ice finely ground and blown in over the packages in the car and by ice in the packages Sometimes

Baltimore and Ohio Railroad

FIG. 4 13 Refrigerated cars bring produce from Texas, Florida, California, and Maine to northern city markets and from northern states to southern cities

bunker ice is omitted with dependence solely upon package and top icing. Newer cars are equipped with axle-driven fans for more efficient air circulation.

Since refrigerator cars are well insulated they are used when actual refrigeration is not needed. They afford considerable protection against freezing. Heaters are placed in the bunkers when necessary.

SALES CHANNELS

The grower of vegetables chooses among many different channels through which to sell his products. His choice is based on comparative costs, prices received, and readiness of sale. No sharp lines can be drawn among the various channels, but they may be roughly listed as follows:

1. To consumers { Roadside. House to house.
2. To retailers { Storekeepers and hucksters and at public market. Hotels and restaurants.
3. To trucker-buyers.
4. To city wholesalers and jobbers.
5. To shipping-point dealers.

Selling to consumers

Roadside selling is discussed in Chapter 5. House-to-house selling by producers is not now as common as in the past. In many cities, there are still hucksters or peddlers who buy on the market and sell in this way. House-to-house selling has good possibilities for the young gardener—4-H and Future Farmer—who can offer a fair variety of goods and a reasonably constant supply. Young salesmen should build business on good produce and good service, not on the willingness of customers to do a favor.

Selling to retailers

For local growers near cities and villages, selling to retailers is a very important method. These sales may be made at a public market such as is to be found in most cities or by covering a route of stores that become more or less regular customers. Trucker-jobbers have important advantages in rendering this service. They can go to market in a city a hundred miles away, be home by 7 or 8 o'clock in the morning, and make deliveries to their customers in time for the day's business. Telephone orders taken the day before delivery help greatly. Trucker-jobber

service, in practice, tends to restrict the variety of kinds and grades available at outlying shopping centers.

Avoid selling too much. Those who sell to retail stores must avoid selling more goods than can be kept in good condition until the next delivery. Nothing blocks sales more effectively than wilted lettuce, shriveled carrots, or soft or spotted tomatoes Retailers should be encouraged to provide cold storage and good display facilities to promote ready sale of goods, for their own and the grower's interest.

Hotel and restaurant trade, largely served by specializing jobbers, demands high quality and dependable service; it is generally willing to pay a little more than retail dealers

Chain-store deliveries are often made to central warehouses, though some of the individual store managers do the buying like any other retailers.

Trucker-buyers

The old-fashioned country buyer of eggs and butter and chickens and meat has found his modern counterpart in the trucker-buyer. He goes to growers and buys a load and takes it to a city market or to a wholesale dealer Considerable controversy has raged around his activities Much depends upon the kind of man he is and the kind of business he conducts. He may be a "fly-by-night," here today, elsewhere tomorrow, according to where he thinks he can make a dime. He is usually a pretty good driver of bargains, calling the attention of the seller to the savings in not having to go to market or to grade or to provide good containers. He often takes goods, if he can get them cheaply enough, that would otherwise be hard to sell. On the other hand, some trucker-buyers are regular in their service at both ends of the line, try to pay fair prices, and so aim to hold a good class of trade.

Selling to wholesalers and jobbers

The distinction between wholesalers and jobbers is not sharp. Wholesalers are generally car-lot and truck-lot receivers, not interested in selling single packages or broken packages to retailers. They sell to jobbers who in turn meet the needs of the storekeeper and the huckster. Many dealers perform both func-

tions, including some very large houses in cities not quite big enough to be called metropolitan.

Forms of wholesale dealing. Growers and shipping-point dealers sell to city receivers under various kinds of understandings. The essential differences have to do with when and where ownership changes.

F.O.B. sales. If the sale is made outright, it is called f.o.b., meaning "free-on-board." The seller delivers the goods loaded on car or truck at the shipping point at an agreed price. Ownership passes when the car door is sealed. Risks in transit are assumed by the buyer. The deal may be made for cash in hand or payable on arrival or on other terms. If the seller is not too sure of the buyer's ability or willingness to pay, he sends the bill of lading (furnished by the carrier) to a bank at the destination with "sight draft attached." Then the railroad will not let the consignee or buyer unload until the money is in the bank. F.O.B. sales are more common when goods are scarce and prices are high. Some good houses do all their dealing on this basis. It calls for integrity and responsibility on the part of both parties, as regards financial commitments, quality of goods, and fulfillment of agreements.

Commission selling. Goods may be sold on commission, the dealer acting only as seller's agent and ownership of the goods remaining with the shipper until the commission merchant has sold it. The risks of transit and sale are carried by the shipper. Common commission rates range from 7 to 12%, and low prices of goods have led many houses to set a 10 cent per package minimum. Commission selling is more commonly employed when goods are abundant, when quality is low or difficult to standardize, or when a shipper is not too well-known.

The desirability of commission dealing depends upon the integrity and selling ability of the house. Some commission houses strictly avoid ownership of any goods and so can claim the advantage of no competition between their own and the shipper's wares. In most states and under federal law, bonding of commission men is required to insure making of returns and fairness in settlement.

Joint account. Shipper and receiver sometimes agree on joint-account sales under which the returns and risks are shared on a definite and agreed basis.

Price-arrival refers to fixing the price when goods arrive, presumably in line with the current market, a common practice among chain-store buyers. This method of selling has aroused much controversy. The buyer dare not treat his sellers too badly or he will not be able to get the goods that he must have. On the other hand, the buyer has an opportunity to set prices at least a shadow on the low side. After all, the success of the deal for both parties depends upon fair trading. The seller needs to know his game and to keep up-to-the-minute. He may be sure that most buyers do just this.

Prevalence of all four types of buying at the same time makes it difficult to appraise the market on a given day. The F.O.B. buyer must guess several days ahead, whereas the price-arrival buyer can close the deal when the goods arrive. On the other hand, the price-arrival buyer may find in times of scarcity that the F.O.B. people have gobbled the supply.

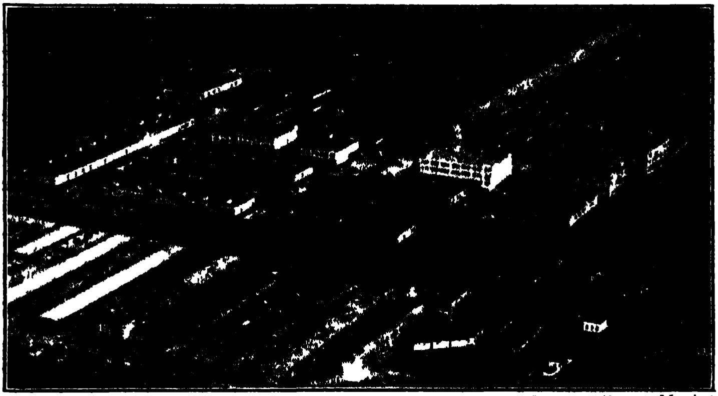
Know the markets. Most produce merchants are keen dealers, and a few may be unscrupulous; it therefore behooves the grower to understand markets and marketing very well. The element of confidence based on integrity is fundamental. Fortunately, there are dependable houses of all types. The shipper urgently needs personal acquaintance with the people with whom he deals. Occasional trips to markets are indispensable if one is to know the market and its "feel" and if he is to get the best service from his agents. This is hardly less necessary when goods are sold outright. Few sellers are so good that they may not slacken a bit when there is no watchful eye.

Selling to shipping-point dealers

Many growers for distant markets use the services of shipping-point dealers, who buy produce, who render more or less service in cleaning, sorting, and packing, who load cars or trucks, and who sell to distant receivers. The same principles of integrity and good service govern here as at the terminal markets.

Cooperative associations often serve as shipping-point dealers. They may do business for members only or for all comers, on contract or not. Cooperatives may render a mere carloading and shipping service, or they may go so far as to operate storage or cannery. They may pool returns, or they may pay the grower what his own goods bring, less costs. The effectiveness, and so

the success, of cooperatives depends upon the wisdom and diligence of directors, the willingness of members to cooperate, and the kind of a manager they can employ. There is no magic about cooperation. A good private dealer is better than a poor cooperative, but the association has definite advantages in democratic management for member interest and in sharing savings. Cooperatives have an extra load to carry if members cannot reach agreement on sound policies, if there are losses to be



Niagara Frontier Growers Coop Market

FIG. 4 14 A vast regional market at Buffalo, including farmer market in foreground, wholesale produce houses, and houses of large food handlers, also railway yards and team tracks

shared, or if the management is less careful of member interests than a dealer would be of his own.

Country auctions, usually cooperative, have become important in areas of heavy production. Costs are low, and there is little opportunity for buyers to "rig" the market. Some auctions have failed because growers have not used them or have used them only for inferior or surplus goods. This probably means that an auction was not needed or that the producers had not grown up to the stage of effective cooperation. Country auctions are numerous and successful in New Jersey.

Selling at public markets

In most cities, there are public markets where farmers sell their goods to buyers who may be consumers, retailers, or wholesale dealers. In some places, notably in Pennsylvania, there are

still many curb markets along certain streets with no buildings and little organization or machinery, perhaps even with no fee. At the other extreme is a great terminal market as at Cleveland or Buffalo where there is a farmer market, rail tracks for unloading, houses for wholesalers and jobbers, and often great buildings occupied by wholesale food dealers.

Markets may be owned by the state or city, by private investors, or by cooperative associations. In New York, markets at Syracuse and Newburgh have been set up under a state-sponsored "Market Authority," a corporation that may borrow money to build a market and operate it. Florida has several great shipping-point markets, state-owned and operated.

Some markets operate in afternoon or evening, saving both grower and grocer an early morning trip. Groceries are increasingly being equipped with refrigerated space to hold goods overnight.

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5

Selling Vegetables at the Roadside

Most people like to sell things. There is a fascination with trade that every youngster experiences, just as at some time he wants to be an air pilot or a cowboy. It begins with the little lemonade stand beside the road, perhaps, and, with some, it persists, until one becomes manager of a farmer cooperative and

FIG 5 1. Striking display of muckland vegetables at Rome, N Y

another gets into big business in the city. The roadside stand affords excellent training in merchandising and brings good returns for produce.

Many successful vegetable growers in all sections of the country have built fine outlets for their products through roadside markets. In some sections, the road may be lined with stands for a mile or two, as at Rome, N. Y., and Hammonton, N. J., but many good-sized communities do not have a single first-class roadside market.

Whether or not to sell at the roadside

Many considerations for and against roadside selling must be weighed one against another.

1. Potential customers, their number, distance, buying power.
2. Suitability of location for a stand.
3. Suitability of the farm to grow a variety of crops over a long season.
4. Competition, local prices.
5. Personal qualifications and choice, availability of help as needed.

One should be on a good road, fairly well traveled, reasonably close to a fair-sized town. A large city is not necessary, and many good businesses are near places of 5,000 people or less. A heavily traveled through route may not be any better than a quiet side road where people like to take peaceful weekend and evening trips.

As roadside selling is a good way to market a variety of crops rather than just one or two, so soil and seasonal conditions should favor such a program.

Personal choice is important. One should like to meet people, should enjoy taking infinite pains with a variety of things, and should be willing to do little else during the busy season.

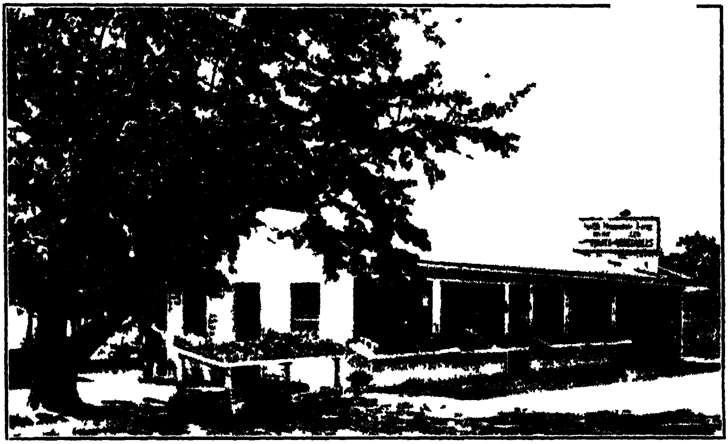
Since the merchandising of produce, from harvest to housewife, is largely a matter of costly labor, it is not uncommon for goods which sells to a dealer for a dollar at the farm to bring three dollars or more at the retail store. The result is that the grower receives less and the consumer pays more than if the two could deal directly. Of course the roadside seller does not realize that whole difference as "velvet," for his own costs and cares are increased as compared with selling in solid cars or truckloads or even with selling to the grocer at a wholesale public market.

The question of Sunday selling is often raised. Some do not believe in working on Sunday, or they feel that six days of work a week is enough for a well-ordered life. Both positions are sound, and roadside marketing does not need to conflict. If customers know that you are closed Sundays, they will come evenings and Saturdays. Of course if you are open Sundays, they will be there; some operators find Sunday their biggest day. Many others do very well operating six days a week and they

stick firmly to their policy, even if for no better reason than that they want to go fishing

Choosing a site

It does not take much to persuade a prospective customer to step on the gas and sail right by a roadside stand If one can see the stand far enough ahead to get off the road easily, if there



USDA

FIG 52 A roadside stand with good display and ample working space

is a smooth place beside the road to slow-up on and if there is ample parking space he is more likely to stop Hills and curves should be avoided Trees in the background and as shade for the stand are desirable unless they obstruct the view An additional parking space on the opposite side of the road is an asset

Building and equipping the stand

Many kinds of stands are in use, from a wheelbarrow by the roadside to elaborate stone and concrete structures Whatever the plan, neatness and attractiveness are important, low cost does not preclude good appearance Make the stand a little smaller if it cannot be both large and attractive If necessary, use second-hand material, but paint it. A rustic type may be put up, using poles from the wood lot, thus saving on lumber Extra temporary structures of canvas or of movable wooden sec-

tions or even of cornstalks may be set up during the busy season. Experiment station bulletins offer suggestions on construction.

Signs

Signs have three jobs to do for a roadside enterprise.

1. *To attract attention and impress a name.* There should be a sign at some distance in each direction so that the motorist may have a chance to decide that he wants to stop and then have time to do it. Some stands have a series of signs beginning a mile away. These signs should be neat and catchy, a bit smart perhaps. Nor should they mar the landscape even though the farmer places them on his own property.

2. *To tell what is available*, though if the stand is sizable and there is a fair assortment, this may be unnecessary. Or signs may call attention to special features: "Precooled Peas," "Sweet Corn with All the Sweet," and the like.

3. *For price tags.* These save time and talk and avoid embarrassment. They may often carry some catchy selling point: "For Big Meaty Slices, Ponderosa Tomatoes, 12¢ per pound." Simplicity, however, should be the rule in sign making.

There is little occasion for untidy signs, though they are common. An art or shop teacher can often help in the design of the larger signs, and their making may be a shop project. It is not hard to develop skill in a simple style of lettering for price tags and small counter signs Much depends on getting suitable cards and suitable marking devices. There are many clever lettering pens to use with India ink; well-chosen wax pencils serve well. Doing little things carefully and attractively makes a favorable impression on customers.

Quality of goods

Roadside business is not built by tourists who are driving through but by the neighbors who come back if they like the goods and the place and the people. If they are not pleased, they do not return. There must be some incentive or they will not be willing to drive out or even to stop when they are going by.

Roadside trade is best built around items that are definitely better when bought strictly fresh Paramount among these are sweet corn, peas, asparagus. lettuce, cauliflower, and spinach.

Muskmelons and watermelons are good leaders too, because their quality is often uncertain in usual retail channels. The tomato is popular and colorful. It is smart business to make your stand famous for quality in some one or two products which are handled as a featured specialty.

Grow quality goods. The first step to insure quality vegetables on the stand is to grow them well, selecting the best varieties and strains, and seeing that all the cultural conditions are favorable: fertilizer, moisture, and insect and disease control. Then considerable pains must be taken to see that produce is harvested only as fast as it can be sold. If second-grade goods are to be sold they should be plainly marked and priced accordingly.

Buying from others

Whether or not to buy from others for roadside sale is a question that often arises. There is no definite answer except the answer of quality. Some good marketers confine sales strictly to what they grow themselves. Others get supplementary supplies from neighbors upon whom they can depend to exercise the same care they would themselves. Also, since the housewife likes to get all she needs of green goods at one stop, some stands handle shipped goods as well. In any event it is well to keep a clear distinction between things grown by one's self or by neighboring farms, and imported items.

Constancy of supply

Roadside selling may be undertaken as a businesslike method of marketing produce in quantity or it may be regarded as a pin-money enterprise to provide a bit of needed cash. On the latter basis it has meant much on many a farm, especially in low-income groups. The trouble is that an attendant cannot be at hand all the time, and customers do not take much interest in stopping when there are only a few items and when a supply may or may not be available. As a business proposition, it is well to plan for a season of reasonable length and then strive to have an assortment sufficient to attract buyers and to justify the full time of an attendant. Roadside selling is a good partnership job for two or three young people. Girls get along splendidly on the selling end.

Careful planning is required to insure a succession of harvests of the desired variety of kinds throughout the season. Special attention must be given to items like sweet corn whose harvest period is short. Tomatoes are easy to have in steady supply. Gilbert Watts, in his book *Roadside Marketing,* shows how he has lengthened his season and smoothed out his sales volume by means of careful planning.

A full roadside program in the north may start with rhubarb, wintered-over green onions, spinach, early plants for home gardens, and asparagus. Then would come radishes, lettuce, beets, and peas, to be followed by the full line of summer vegetables, carrying on until frost. Then, with root crops, potatoes, sweet potatoes, cabbage, celery, squash, and pumpkins, sales could be maintained about as late as one chooses. Similar successions may be planned for other regions.

A suitable storage place is an important adjunct for a roadside stand. House or barn cellar or outdoor cave will serve for common storage for several months in the fall. Such a place is also useful for overnight and other temporary keeping of things that do not deteriorate rapidly. A corner may be partitioned off to be cooled with ice or refrigerating machine as need arises and capital becomes available.

Arrangement and display

One of the best sales-promoting features of a stand is the display of a large amount of produce. At the same time, with many vegetables, this cannot be done if quality is kept up. A compromise is necessary. Shallow sloping trays or shelves can be used for display. Some products that move in fair quantity, such as tomatoes, can be massed. Baskets set on the grass can be spaced out a little. Pumpkins, squash, and watermelons show up well and do not deteriorate too rapidly. On the stand itself, products should be kept constantly in good order.

Packaging should be gauged to suit the convenience of customers. Tomatoes can be sold in small baskets when they are high priced, early in the season. Later, when canning begins, larger packages may be offered.

Flowers afford a splendid accessory for a roadside stand. There is no better decoration. Customers are flattered if they

receive a little bunch of sweet peas or a few gladioli or asters. And there are possibilities of their sale as well.

Selling methods

Price policy. No rules can be laid down about prices. A fairly suitable starting point is to ask prices intermediate between wholesale farmer's market prices and town retail prices, because labor costs are higher than for quantity sales. Customers are pleased if they can save a little under retail store prices. One need not expect, however, to be under the lower chain-store levels, if high quality is offered. Some commercial stands receive prices about in line with the best retailers, holding their trade through special attention to quality that is not only high but also dependable.

Salesmanship. One of the prime factors in successful selling is the salesperson. Appearance, personality, and manners all count. To be patient and still get through and on to the next customer; to be pleasant without palaver; to correct a mistaken idea without contradicting—these call not only for natural aptitude but for study as well. Cleanliness and neat attire are essential, though that does not necessarily mean being "dressed up." The ability to slip in a convincing selling point, a suggestion on how to make a tasty dish, or a tip on how to keep the goods nicely for a couple of days builds favor and good will. Needless to say, there should be no misrepresenting of goods. Usually hired help is more likely to err in this respect than the grower himself. Readiness to render a little extra service, especially when trade is slack, will help win and hold customers. If the customer is dissatisfied, replacement of goods costs little and builds good will. One speedily discovers those who are inclined to take advantage.

Advertising

The form and amount of advertising must be decided in the light of local conditions. An advertisement in a small-town paper costs only a small sum and reaches people who are within reasonable distance of the farm. An advertisement in a big city paper costs heavily, and the percentage of readers within reach of the stand may be small. One of the best plans is to learn the names of customers and so build up a mailing list. Then use

postal cards when there is something special to offer, telling housewives that this is the time to can tomatoes, that watermelons are just coming in that a special planting of lettuce for fall salads is just ready Make the copy and design good enough so that people look to your cards as news Also, printed bags go to the kitchen and are likely to be seen by neighbors

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6

Equipment

For home garden, see Chapter 2.

FOR COMMERCIAL PRODUCTION

For commercial vegetable production, equipment may be as simple as for the home garden. Many a young 4-H Club member or Future Farmer has made in a summer enough money to meet part of his school expenses, with equipment that a ten-dollar bill would cover. On the other hand, the high cost of labor has led commercial growers to use more and more equipment. How much and what equipment depends on size of operation, crops to be grown, climate, and type of soil. No prescribed list can be made out.

Equipment investment must be watched closely. Equipment offers ways of doing things more cheaply and better. Lack of suitable and adequate equipment may greatly increase the cost per unit of produce. On the other hand, many a farmer is machinery-poor. Some people's eyes get very big when they buy equipment. In taking on a large truck or tractor that is needed for a few weeks each year but that cannot be kept profitably busy very much of the time, one should remember that depreciation and interest go on every day, whether the goods are bought outright for cash or on partial payments. The utmost realism is necessary in figuring probable use and gains against costs in interest, depreciation, upkeep, and operating expense. Also, it is often cheaper to hire for a short time than to own. On the other hand, equipment owners sometimes do custom work for others.

Judging the merit of equipment. Having decided that a piece of equipment can be used with profit, the buyer seeks assurance on certain points. Seldom does one find a machine that meets the ideal, but quality is constantly improving.

1. *Effectiveness and suitability* for the work to be done. A machine is expected to do its work and do it well.

2. *Design.* Substantial construction without undue weight requires careful choice of metals and other materials; proper design of shapes, forgings, and castings; suitable bearings to reduce friction; proper provision for lubrication; and good gears, clutches, and power-transmission devices. Great advances have been made in all these directions, but the policies of manufacturers differ in the conflict between cost and design. Very often, good design does not increase the cost.

3. *Good or poor workmanship* is evident to one who has gained some experience with machinery. Jagged corners on nuts, rough surfaces, and clumsy design at visible points are likely to be associated with poor machining and finishing in working parts.

4. *Simplicity, dependability, durability, and speed of operation.*

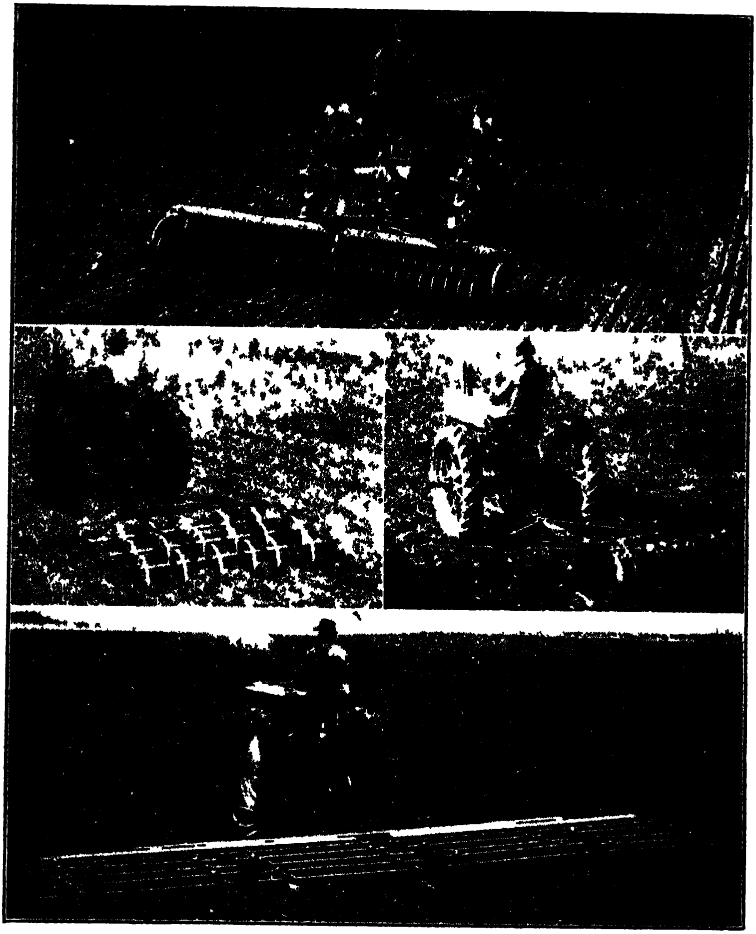
5. *Service* in parts, adjustment, and repair should be available within reasonable distance, and four years later as well as at the time of purchase.

Buying equipment. In general, purchases should be made from established houses of long experience and integrity, which provide courteous service and are likely to continue in business.

One of the first steps is to find out what different makes are on the market. Then get the catalogues and study them, separating flashy selling talk from statements of fact. Some sales literature is of real educational value, containing manuals of information, specifications, and engineering data.

The next step is to think out clearly what one needs. Then talk to the salesmen, whose contributions may throw light on the best machine to meet the need. Ask about features that mean most in the use of a machine. Buying is an active job, not a passive one. It takes judgment and common sense to steer a path between random buying on the one hand and becoming entangled in a maze of unessential details on the other.

Always see a machine in action if possible, preferably under actual conditions of use. The price is not the only guide on performance. A rather inexpensive item may last for years. If a machine does not work well, the delay, inefficiency, and annoyance last a long time. Fairs and shows do a real service in displaying many makes of equipment, far more than may be found in a town or even in a good-sized city. Well-posted sales-



John Deere Company

Preparing the soil

Fig. 61 Clod crusher

Fig. 62 Spring-tooth harrow

Fig. 63 Disc harrow

Fig. 64 Spike-tooth harrow

men are usually at a fair or show, as they may not be at a small agency. At meetings and field days, one can see demonstrations of many forms of equipment.

In summary, a well-informed buyer, knowing about what he wants, dealing squarely and reasonably, can have very helpful sales service from good concerns.

CARE OF EQUIPMENT

Just a little extra money may well be invested to procure equipment made for good service and long durability. Neither good service nor long life can be secured without good care.

The principal items in the care of equipment are:

Lubrication. The dust and dirt of the farm are enemies of bearings; oil and grease are the protectors of bearings Follow with care and regularity directions about kind of oil and frequency of use.

Tightening and adjusting. Many a machine is gravely damaged by shaking and racking due to looseness A little motion where there should be none develops more motion, for wear is rapid where there are no bearings Proper adjustment governs efficiency of operation as well as power demand

Rust protection. Implements, whether two-dollar hoes or $150 gang plows, will not work well if rusty Rust forming under moist soil makes a rough coat on steel surfaces that is very hard to remove. Oil applied with cloth or brush or spray, immediately after use, is a good safeguard

Overhauling. Greyhound buses seldom break down on the road. That is partly because repair men do not wait for trouble Overhauling is periodic and regular The cost of machinery failure on a vegetable farm is out of all proportion to the cost of keeping things in order. The off-season—winter in the north, summer in the south—is the time to go over all equipment thoroughly. A cotter pin replaced in January may save a crucial day of planting in April. Worn parts are best replaced before they give way and possibly result in other damage.

Keeping tools sharp—not only axes and scythes but also hoes —is real economy. A good motor grinder is invaluable, and hoeing gangs should carry coarse files.

Housing of equipment protects against sun and rain, sand and dust. Order in storing equipment saves both space and time. A good storage place is a good repair room.

Avoid losing things. Losing things costs money on every farm. The monkey wrench is left by a fence post, a crowbar where a rock was moved. Larger items disappear when weeds grow up, and still larger ones when the neighbors forget to return them. A good rule is a place for each and each in its place. Some farmers use a wall board with painted silhouettes for small tools; larger items have regular places in sheds. If an item is missing its absence is soon noticed. But devices are only aids. Constant watchfulness is essential.

POWER FOR THE VEGETABLE FARM

About 1900 a large share of vegetable farm work was done by man power, but the horse was important. By 1925 improved implements had reduced man-labor requirements and increased the load of the horse. Today, the tractor dominates but neither horsepower nor man power is obsolete.

Man power still does the things that machines cannot do. But men do not want to do some jobs, even though such tasks as transplanting can sometimes be done more cheaply by hand than by machine.

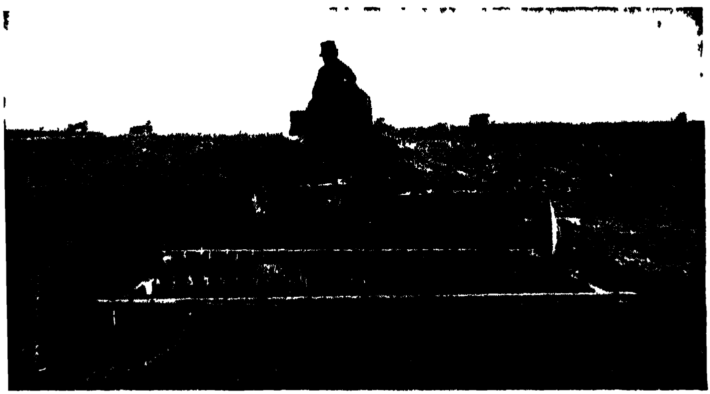
The horse is useful where there is a good deal of standing along with the moving, for field trucks, putting out plants or picking up produce. Tractor and truck have found countless new adaptations and are better controlled than ever, but the value of the horse is sometimes overlooked.

The tractor. Tractors can work twenty-four hours a day, do not demand feed when not working, and are little influenced by the weather. For a good statement of the comparative advantages of horse and tractor, see Jones,[1] page 14. A large number of vegetable farms are horseless; many use both horses and tractors. Few sizable operators are without a tractor of some sort, and very few are without a truck.

Power units on vegetable farms range from little walking garden tractors to huge track-layer diesel-powered juggernauts.

Garden or walking tractors, ranging from ½ to 4 horsepower, are valuable for cultivation but not commonly for plowing or

haulage. They are of special value in operations where working close to walls or ditchbanks is desirable and where intensive operations forbid waste of space. They are very useful on smaller vegetable farms.



C. O. Jeliff Mfg. Corp.

FIG. 65. Meeker harrow for fine finish for small seeds. Available also in small sizes.

General-purpose or row-crop tractors of 8 to 20 horsepower have been made much more adaptable to many kinds of work through development of adjustable track-width, the use of rubber tires, the attachment of tools directly to the tractor, and increase

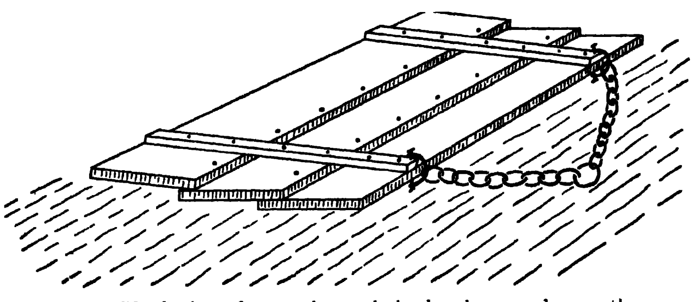


FIG. 66. Plank drag for crushing clods, leveling, and smoothing.

in vertical clearance. Improvements have also been made in shortness and quickness of turn and in actual control of tools. Tractors are generally fitted for belt work, for drawing other tools such as manure spreaders or potato diggers, and for hauling

farm trucks or trailers. Low platform trailers are very useful on the farm.

Large tractors are found mainly on large-scale operations where heavy power is required for plowing, making up beds, and the like. One is impressed with the heavy calibre of all equipment in the great truck-growing districts of the south and west.

Rubber tires for farm machinery have gained wide usage during recent years. McCuen and Silver [7] report that low-pressure pneumatic tires, in comparison with metal wheels, cause less rolling resistance (thus reducing the power requirements of the tractor), decrease the fuel consumption, permit the performance of a wider range of jobs, run at higher speeds, stir up less dust, and provide greater comfort for the rider. They are rather costly, but their life is long if good makes are purchased.

Trucks. The same principles apply to the purchase, operation, and care of trucks as of other equipment.

The vegetable farmer's truck is called upon for many kinds of service, not only taking vegetables to market but also bringing them from the field and hauling supplies, plants, etc.

Studies have shown that ton-mile cost of truck transportation declines as the load and mileage increase. Little-used trucks are very costly.

It is unwise to buy an oversize truck if large loads are carried during only a few weeks. Also, trucks of, say, a ton rating may be equipped with springs and tires to permit considerable loading above the normal rating. Some consideration must be given to the possible need for refrigeration and insulation.

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Commercial concerns have good pamphlets on the principles, care, and use of equipment, in addition to sales catalogues.

7

How Plants Grow

The mystery of the change of an apparently lifeless seed to a vigorous growing plant never loses its freshness and constitutes indeed no small part of the charm of gardening.
—E. J RUSSELL, *Soil Conditions and Plant Growth.*

The elements of science throw light on how things happen in plants and so help us control the growth and performance of plants. Botany and chemistry achieve new and fascinating interest and meaning when connected with practical farming.

Do not imagine that the elements of basic science are especially difficult. Young people can understand very well, as is evidenced by what 12-year-olds commonly learn about radio and airplanes if they are interested. In studying this chapter, go back first to a good elementary botany textbook, reviewing the main facts about higher plants and connecting these facts with crop problems. Then keep the book at hand so that you can look up, in text or glossary, words whose meaning has been forgotten. Do not let words or sentences slip by without understanding them. An unabridged dictionary is often an easier place to find specific information than a textbook.

The following statements, being very brief and general, cannot tell the whole truth, and there are wide variations among the kinds of plants.

Structure and function

We are concerned, first, with the plant parts which make up its *structure*. Structure is treated in the branches of botany called morphology and anatomy. Histology deals with the tissues. We are concerned, second, with what the plant does and how it does it, with *function*, physiology. Cytology includes both structure and function in the study of the cells. Taxonomy has to do with description and orderly classification of kinds of

plants. Ecology treats of the relation between the plant and its environment. Structure and function are clearcut concepts, but each is dependent upon the other, and their relations are closely interlocked.

Vegetables belong to the group of the higher plants, that is, the plants that are highly organized with very specialized parts and processes.

Plant parts

Most higher plants possess root, stem, leaf, flower, and fruit.

The parts of plants which we use are very diverse. In a single genus, *Brassica*, we find use for the root of the turnip, the stem of kohlrabi, the leaf of kale and collard, the exaggerated terminal bud of cabbage, the axillary or side buds of Brussels sprouts, and the inflorescence or flowering head of cauliflower and broccoli. Familiar fruits are tomatoes, melons, and beans. Most edible parts represent exceptional development of tissues and structures; cells are larger and more numerous. The root of beet is larger and more tender than that of Swiss chard. In the beet, as in many vegetables, better quality is associated with rapid growth and large, thin-walled, succulent cells.

Roots serve for anchorage and support for plants and for intake and transport of water and nutrients from the soil: nitrogen, phosphorus, potash, and a number of minor ones. Roots possess characteristic structure different from that of stems. They branch freely and make their way through the soil, coming in contact with soil particles. Root hairs are the principal absorbing organs, taking in water by the process of *osmosis*. Look this word up if you have forgotten its meaning. In the water of the soil, nutrients are in solution, and they pass into the plant by diffusion through the membranes of the cells.

Stems constitute the above-ground frames of plants, furnishing support for their parts and channels of transport for water, and for dissolved nutrients to pass from the roots and dissolved food materials from leaves, each to the places where they are utilized in growth. Stems have their characteristic structure of pith, xylem, phloem, cambium, cortex, and epidermis or bark. Each of these tissues is specialized in both form and function. A stem may be so short as to appear a mere disc, especially in

young plants of lettuce or celery. When the plant goes to seed, the stem lengthens.

Leaves arise from stems, and their principal functions are transpiration and photosynthesis.* Transpiration is the evaporation of water from leaves It is the outflow of the stream of

E. I. du Pont de Nemours

Fig 7 1 Tomato flower clusters--close up Learn to look for details of plant parts such as this picture shows

water which has entered through the roots, some of which has taken part in the vital activities of the organism. Most transpiration takes place by diffusion of water-vapor through the stomata, minute openings in leaves, with a valve mechanism of guard cells which closes the aperture when water is scarce and turgor declines. It is through these openings also that carbon dioxide for photosynthesis and oxygen for respiration diffuse into the plant from the air.

* *Photos*, light; *syn*, together; *thesis*, putting

Trans, through; *spirare*, to breathe. This is not true breathing, as in respiration

Flower and fruit are concerned with sexual reproduction. The parts are considered to be modified and specialized leaves. Petals are like leaves in structure if not in color. Double rose flowers show various forms of petals, ranging from the usual shape to typical stamens. The open pod of a pea illustrates the leaflike nature of the carpel or ovary, which is part of the pistil. Fruits are developed and matured ovaries.

The cell is the unit both of structure and of activity in plants as in animals. It consists of a cell wall and a living protoplast. In the protoplast is the nucleus, which plays a special role in cell division and in inheritance. In the cell there may be a vacuole of water, bearing substances in solution; plastids; and other materials in crystalline, granular, or droplet form. Water enters or leaves the cell by osmosis, and it may leave by evaporation. Soluble substances move from cell to cell by diffusion. Cell membranes are differentially permeable; that is, some solutes can pass through, but others cannot. Permeability greatly influences movements of materials within the plant. One kind of plastid, the chloroplast, is the seat of photosynthesis.

PHOTOSYNTHESIS

Photosynthesis is the combining chemically of carbon dioxide and water, by means of the energy of light, to make sugar. Oxygen is released, and it passes out to the air or is used in respiration. The green chlorophyll of the cells of the leaf is the active agent in photosynthesis. No one seems to know the exact chemical steps in this process. Enzymes play a part. Expressed in a formula, the overall reaction is like this:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Sugar, a carbohydrate, is the basic material of plants from which other materials and structures are built up. It is also the form in which energy is transported to other parts of the plant, and it furnishes the energy for many of the activities of the plant. Transformable into other carbohydrates and carbohydrate derivatives, sugar serves as the energy-storage material of plants, like the coal stored in the cellar of a house. Carbohydrates furnish most of the power that man uses, the energy of burning wood

and coal and gas and oil, as well as man's own energy and that of the animal power he uses. Water power is our only important source of energy independent of photosynthesis.

Conditions for photosynthesis

Anything that stops or slows the process of photosynthesis tends to retard growth and the making of a crop, subject of course to other factors which may be limiting. If food material is stored for a time, as in asparagus, the effec is simply delayed until the next season. Among the conditions that commonly interfere with photosynthesis are deficiencies in: (1) light; (2) carbon dioxide; (3) minerals necessary for the process, notably iron and magnesium; (4) temperature; or (5) water. To this list we must add (6) the activities of plant enemies, principally insects and diseases.

Light is a form of radiant energy of wavelengths visible to the human eye. Light supplies the energy for the process of photosynthesis.

When the sun shines only a small fraction of available light is actually used, but in short days and cloudy weather light is often the limiting factor.

When light encounters surfaces, it is partly reflected and partly transformed to radiation of a longer wavelength which we call heat rays. This happens when light falls upon plant surfaces, raising the temperature of the tissues, hastening transpiration, respiration, photosynthesis, and other plant processes, and also furnishing energy for photosynthesis.

The effect of light upon plants depends upon its wavelength or its place in the spectrum (color), upon its duration, and upon its intensity.

In photosynthesis, the blue and part of the red sections of the spectrum seem to be more effective than the orange, yellow, and green. Normal ultra-violet radiation does not seem to affect the well-being of plants one way or the other.

Duration of light, referred to as length of day or photoperiod, has an important bearing on the quantity of carbohydrate produced in photosynthesis. It profoundly influences the production of flowers and seeds. Some plants, like spinach, produce seed or "bolt" when days are long. No important vegetable is characteristically a short-day plant, but among flowers the wild

asters and goldenrod do not bloom until days shorten. Light is not alone in governing reproduction, as temperature is perhaps even more significant with the vegetable crops. See page 97.

Carbon dioxide (CO_2) is greatly diluted in the air, being present as only 0.03% or 3 parts in 10,000, yet this amount is sufficient to furnish the carbon for the vast tonnage of new plant material that is made every year. Growth has been promoted experimentally by increasing the percentage of carbon dioxide in the air, and manure is considered to help by releasing carbon dioxide, thus increasing its concentration in the air about the plants.

Low temperature retards photosynthesis. Photochemical reactions themselves are independent of temperature, but other chemical processes are dependent upon it.

Water deficit does not retard photosynthesis directly but often indirectly by causing wilting and stomatal closure which interferes with gas exchange.

Insect or disease injury which destroys foliage is a very common hindrance to photosynthesis, reducing both yield and quality of the crop.

Products

The simple sugar glucose, $C_6H_{12}O_6$, is soluble and readily transported to all parts of the plant. It undergoes numerous chemical transformations to furnish many kinds of materials. *Starch* is an important storage form, readily changed back, by enzyme action, to sugar. Further condensed, it produces cellulose and lignin, furnishing materials of structural strength for the plant but making vegetables tough and hard to eat. *Proteins* are nitrogen-bearing compounds, very important in the life activities of the cells, especially in the nucleus. Many other kinds of compounds have carbohydrate material as their base, among them fats and oils, the various ingredients that give flavor and color, waxy and corky substances, and cementing materials (pectins).

The minerals play various roles as constituents of specialized chemical compounds. For example, phosphorus is important in the proteins of the cell nucleus, which governs the business of growing. Magnesium is an essential constituent of chlorophyll. For a brief statement of these roles, see Thompson's *Vegetable*

Crops, fourth edition, pages 57 to 64, or a general botany or plant physiology.

RESPIRATION

All plant processes, like the activities of animals and machines, require energy or power. This is true even of thinking. Whatever we know or do not know about how a plant lifts water from soil to the growing point, we are sure that power is required to do it, and that power comes from respiration.

In plants, energy of light is changed by photosynthesis into latent chemical energy in the making of sugar. Sugar then moves in the plant sap to other parts where processes of growth are going on. At these points, the energy of the sugar becomes available and active through the process of *respiration*, which is the reverse of the process of photosynthesis. Carbohydrate is oxidized under enzyme action, taking up oxygen and separating into carbon dioxide and water with release of chemical energy which is used in growth and other processes. Some energy is released in the form of heat, which then is either dispersed into the air or is used in various plant activities. In formula, respiration looks like this:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

The carbon dioxide is dispersed into the air; the water enters the sap stream to be used or transpired. Respiration goes on as long as the tissue is alive, in active plants, in harvested products, and, very slowly, in stored seeds. In some vegetable seeds life and respiration are known to have lasted as long as 15 years or more, and in some other seeds, much longer.

TEMPERATURE AND PLANT PROCESSES

Assuming that water, nutrients, and light are available, plants grow fast in warm weather, slowly in cold weather. This refers to the range of temperature between the freezing point and the point of heat injury. On freezing, living matter is usually seriously damaged, largely by water loss from the cells. The freezing point varies with the concentration of solutes in cell contents, and some plant tissues are able to withstand temperatures below the freezing point of the juices. Wright gives freezing

points of vegetables, fruits, and flowers in *USDA Circ.* 447, 1942. The point at which heat injury occurs is less definite. Injury may be due to increased evaporation, precipitation of proteins, or other changes.

Plants are not very active at temperatures below 43° F. (6° C.) or above 110° F. (43° C.). Between these points there is, presumably, for each species, a level of maximum activity.

Kinds of plants differ as regards the maximum or minimum at which they can grow. Watermelons and sweet potatoes do well at high temperatures, poorly at low. Peas and spinach reverse this situation. Between these limits, temperature may influence different processes in different ways and at different levels. It may also act indirectly, as by increasing the growth of a fungous disease which may injure the plant.

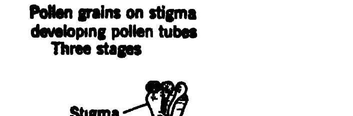
Law of van't Hoff. One of the most important of the temperature relations is clarified by applying the principle that governs the effect of temperature on chemical reactions. Most of the constructive changes and many of the destructive ones that go on in the plant and its products are chemical in their nature. *For every 10° C. (18° F.) rise in temperature, the rate of chemical reaction is approximately doubled.* There are wide variations in the application of this *law of van't Hoff* in plants, depending upon other factors, upon other effects of temperature, and upon the kind of plant. The rate may not be doubled but multiplied by a different factor, as 1.70 or 2.25 instead of 2. This factor is called the temperature coefficient, or Q_{10}. When we learn that an observed Q_{10} value does not conform to the theoretical value of 2, we need not assume that the law is invalid but rather that factors other than temperature and other effects of temperature enter the picture.

When we realize that photosynthesis, respiration, the making of proteins, and many other processes are at least roughly governed by this law, we get the meaning of the farmer when he says, in hot weather with ample moisture, that "corn jumped ahead last week," or "watermelon vines raced across the field."

High temperatures increase rate of evaporation, especially if the relative humidity of the air is low. This retards growth and, in harvested products, speeds deterioration. For the effect of freezing temperatures, see page 96.

LIFE HISTORY OF A PLANT

When a viable seed is placed in the soil, it begins to grow if three necessities are provided: moisture, heat, and oxygen. The baby plant has already taken form as the embryo within the seed. As it grows, the root develops into the soil, branching and forming root hairs just back of the root tip. The cells of the growing point of the stem, called meristem, undergo repeated division As this goes on, some cells differentiate into one kind of tissue, others into another, for example, into phloem, xylem, or cambium. A cell, after division, increases in size, and then it matures. In many tissues, maturity includes the strengthening and hardening of walls and the development of special forms and functions.* For example, in leaf cells and some stem cells, chloroplasts are formed and photosynthesis begins. Branches, leaves, and, later, floral parts are built up. The processes of photosynthesis and respiration have already been discussed.



After L. W. Sharp, Cornell University

FIG. 72 Fertilization in a flower (diagrammatic).

Reproduction is accomplished either sexually or asexually (vegetatively).

Vegatative reproduction involves various forms of branching, among them, development of underground stems, bulbs, tubers, or roots that are capable of budding. Some plants, as the tomato and sweet potato, will form roots if above-ground branches are buried, and so continue growth after being cut off from the parent.

* Beginning students should learn to differentiate clearly between concepts of form and function. See page 90.

Sexual reproduction is a complex process. Students who have had course work in botany, perhaps as part of general science, should review the story of sexual reproduction, the meaning of *alternation of generations*, the reduction divisions, and the processes of pollination and fertilization. Figure 7.1 is intended to aid in this review.

The nature of seed

A seed is a ripened ovule and consists normally of three parts: (1) The embryo, a little plant that has developed from fertilization. (2) Reserve material for energy and growth. This may be stored (*a*) in a tissue, *endosperm*, which has developed from a secondary fertilization, or (*b*) in the *embryo*, chiefly in cotyledons. (3) Seed coats, tissues developing not from fertilization but as part of the mother plant.

Some seeds are accompanied by other parts of the mother plant, such as carpel walls, as in lettuce and carrot; thus what we call a lettuce seed is really a fruit. Floral parts may persist, as the chaff or glumes in sweet corn. Even parts of the inflorescence may accompany the seed, as in the seed ball of beet. Many people who have planted beets all their lives have never seen a beet seed, shining brown, soft-coated, imbedded in the fruit, enclosed in thickened, dried, and hardened calyx lobes, and mounted, one to four or more, in a cluster on a bit of the plant stem. A good adventure in seeing things consists in soaking and dissecting a seed ball and identifying these parts.

In some plants, seeds ripen and go into the inactive or resting state when the embryo is very young and relatively undeveloped. A good illustration is carrot seed. When favorable conditions are provided, growth is slow for some time. In the radish and bean, the embryo is further advanced at the time of the ripening of the seed, cotyledons and plumule being highly developed and endosperm reserve having been consumed in embryo growth. Such seeds germinate quickly and vigorously. Seeds of the first group must be managed delicately; seeds of the second group can break through a fairly heavy or even slightly crusty layer of soil.

INHERITANCE AND BREEDING

Environment and heredity

The influences that affect the development of a plant fall into two categories or groups: *environment* and *heredity*. Environment includes all the conditions that surround the plant: temperature, moisture, atmosphere, soil. Heredity refers to the inheritance or passing on of characters from one generation to another, the inherent nature of the plant. People sometimes debate which of these is more important. There is no point to the question, for the effect of heredity is curbed or changed if environment does not favor normal growth. A plant may have the hereditary factors for ample chlorophyll but, if magnesium is absent, chlorophyll is not formed. Heredity is sometimes defined as a plant's capacity, transmitted from generation to generation, to respond in a given way under a given set of conditions. Thus desirable hereditary characters may be nullified by unfavorable environment. No excellence of environment can bring out characters that are not present by heredity.

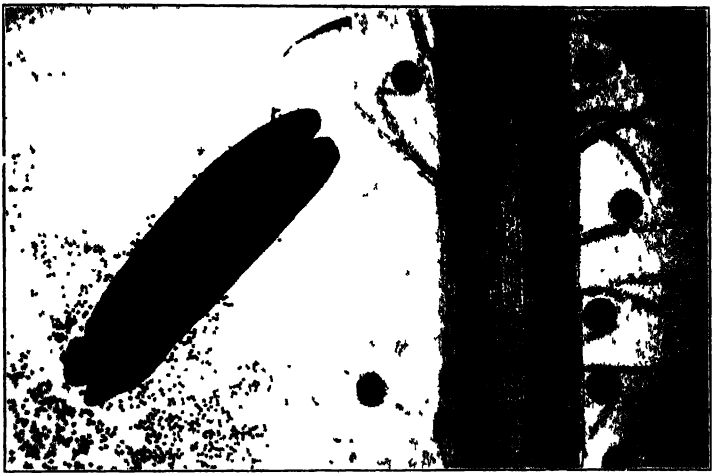
Mechanism of inheritance

It is generally accepted that the chromatic material of the cell nucleus, set in order in the form of chromosomes * at the times of cell division, carries in some way or other the hereditary elements that govern the characters of the progeny. Each character is conceived to be controlled by one or more factors or genes. Microscopic study of plant cells coupled with observation of the characteristics of the growing plants has led to definite location of genes at certain places on certain chromosomes No one, however, has seen a gene or knows what it is.

Chromosomes and genes. Chromosomes in a nucleus are paired, one coming from the paternal side, and the other from the maternal. Each of these two chromosomes possesses a series of homologous or corresponding genes, each gene concerned with

* A chromosome is a body of protoplasm, of material called chromatin, present in the nucleus of the cell. It is the carrier of the genes, which are the determiners of hereditary characters. Species of plants have definite numbers of chromosomes, and genes are assumed to be arranged in definite patterns on the chromosomes. For full discussion see one of the newer elementary botany books or a book on genetics.

a given character. Thus at a certain point on each chromosome in corn is a gene governing color of kernel, say white or yellow. If both genes are for white and the plant is self-pollinated, the progeny will show white kernels; if both are for yellow, the progeny will show yellow kernels They are said to breed true; they are *homozygous*. Now, if the homologous genes are different, paternal for white, maternal for yellow, progeny will show



Associated Seed Growers, Inc.

Pollination in corn

FIG 7.3 Pollen shedding (dehiscing) from anther

FIG 7.4 Pollen grains find rest on silk (style) with aid of tiny hairs. Some grains are germinating

some plants with white kernels, some with yellow. That is, the plant does not breed true; it is *heterozygous*. Usually one character or the other is *dominant* This means that an offspring plant that starts with two genes for white will be white, a plant that starts with a white and a yellow gene will be yellow, as will the one with two yellow genes. Genes are designated by large and small letters: Y for yellow, y for white or absence of yellow. If a heterozygous plant (Yy) is self-pollinated, YY, Yy, yY, and yy will be produced in equal proportions. Consequently, three of every four plants will have yellow kernels and only one will show white. This kind of relationship can be followed out for many characters and many generations, and

even in complicated situations the observed characters check closely with theoretical expectation.

Some characters as for size of fruit and sugar in sweet corn are governed by more than one pair of factors or genes, often with incomplete dominance. In the segregation generations (F_2) * they show many gradations between the parental types. Accordingly such characters are *quantitative* in their inheritance and therefore are not so readily worked out as characters that show two distinct alternatives and are known as *qualitative* characters.

Mendel's law. Understanding of these relationships dates from the rediscovery of a paper by Gregor Mendel, an Austrian monk, whose work lay unnoticed in a little-read scientific journal from 1866 to 1900.

Understanding of the laws of heredity has been of untold value in practical improvement of plants, leading from the uncertain and laborious methods of random crossing and the search of vast populations to the orderly crossing of plants possessing various desirable and undesirable characters to yield plants of the desired combinations of characters.

Practical breeding. When, by self-pollination and selection, a strain of plants is developed that is homozygous for the desired characters, it will "breed true" and is readily maintained. To illustrate, I. C. Jagger found that a muskmelon from India was resistant to powdery mildew, a fungous disease, but was not a good market variety. The varieties in use were desirable for culture, marketing, and eating but were commonly ruined by the mildew. The two varieties were crossed, and out of the very diverse progeny were selected plants of a type that met both requirements. Thus was developed a new variety called PMR 45, meaning powdery mildew resistant. In 1939, a new strain of mildew appeared to which PMR 45 is not resistant, and so more breeding work was conducted and a new strain PMR 5 was announced. Today the breeder is able to decide on a combination of characters that would be good, to make a blueprint, so to speak. He can examine many varieties and find the desired

* F_1 refers to the first generation after crossing; F_2, F_3, etc., to successive generations from that cross. An F_1 progeny is usually uniform in its characters, and segregation or breaking up into varied types is usual in the F_2 generation.

characters. Then, he can cross and recross and back-cross, selecting all the while until he finds plants combining the various qualities he seeks. Furthermore, he may reduce his strain to a pure line or homozygous state, and he is then ready to offer it to the world. Many of our varieties of vegetables have been developed in this way.

Mutation. Breeding as thus described brings no new characters. It is merely the recombination of characters that already exist. However, changes in "germ plasm," called mutations, sometimes occur suddenly. A sweet potato may be found, three-fourths of which is a pale yellow and one-fourth dark yellow. If plants are grown from buds on the light yellow part, pale yellow potatoes are produced; from the other part, dark yellow. These characters of root color are found to be inherited like other characters.

Changes in chromosomes and corresponding changes in characters have been induced by treatment with certain chemical substances and with various forms of radiation. Many of these changes are associated with changes from the normal number of chromosomes. These methods have not thus far resulted in significant improvements in our vegetable plants.

Hybrid vigor. Continued inbreeding or selfing in some instances, notably with corn, results in decline of vigor of progeny. This tendency is corrected and vigor is even increased when two well-selected pure line inbreds are crossed, and at the same time great uniformity of progeny is achieved. The phenomenon is called *heterosis* or *hybrid vigor*. We now have many fine varieties of sweet corn developed in this way. The breeder must maintain the inbred lines year after year, cross them every year, and so be able to sell seed. The principle is applicable to other kinds of plants, notably open-pollinated * ones.

Although sweet corn is the most notable case of vegetable improvement by use of this technique, hybrids are available in onions, tomatoes, summer squash, cucumbers, and several other kinds. Cost of emasculating and pollinating has been an obstacle, but development of male-sterile lines has been useful, notably in onion, tomato, and now in sweet corn.

* Close-pollinated refers to kinds such as bean and tomato which are normally self-pollinated; open-pollinated to those in which crossing is usual as corn and cucumber.

VEGETATION AND REPRODUCTION

Gardeners have long observed that plants of a given kind may behave very differently as regards production of leaf and stem in relation to production of flower, fruit, and seed. The former is called vegetative growth, the latter reproduction though, strictly speaking, it should be described as sexual reproduction. These performance differences—"running to vine," "running to seed," and "bolting to seed"—often spell the difference between profit and loss.

Spring-planted spinach of some varieties speedily bolts or runs to seed; when planted in the fall, it makes a strong cluster of leaves and does not bloom until the following summer. Celery and cabbage crops sometimes produce seed stalks which make the plants unmarketable. Peppers and tomatoes are subject to excessive vegetative growth, making little or no fruit.

Many years ago a German investigator, Klebs, became interested in the factors that govern the balance in plants between vegetative and reproductive growth. Klebs had surmised that external conditions influence or modify conditions within a plant and that these internal conditions in turn influence the plant performance as to vegetative and reproductive growth.

Tomato

Carbohydrate-nitrogen. In 1918, Kraus and Kraybill,[10] following the thought of Klebs, made chemical analyses of carbohydrate and nitrogen in tomato plants and associated four combinations of vegetation and fruitfulness with the relationships which they found between these two groups of materials.

1. *Non-vegetative and non-fruitful,* plants low in carbohydrate and high in nitrogen. This condition can be induced by removing leaves or shading.

2. *Vegetative and non-fruitful,* plants well supplied with both carbohydrate and nitrogen. Such plants are said to have "run to vine," sometimes because of high nitrogen and high moisture in the soil, sometimes because setting of fruit has been interfered with by other factors such as insects or hot drying atmosphere.

3. *Vegetative and fruitful,* plants with ample supply of carbohydrate and adequate but not excessive nitrogen resources, conditions favorable for an excellent yield of fruit.

4. *Non-vegetative and non-fruitful*, plants well furnished with carbohydrate but undersupplied with nitrogen.

Interpreters of Kraus and Kraybill's work applied the term carbohydrate-nitrogen ratio, based on analysis of the plants, a concept that is faulty as it implies that both factors, carbohydrate and nitrogen, are linked in a quantitative manner. The ratio can change materially without affecting the vegetation-reproduction situation, as for example when nitrogen continues

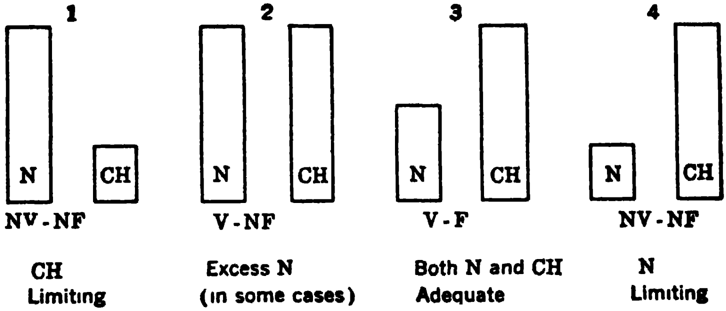


FIG. 75 Illustrating four categories of vegetation and reproduction of Kraus and Kraybill[10] See text

N = nitrogen; Ch = carbohydrate; *V* vegetative, *F* = fruitful; *NV* = non-vegetative, *NF* = non-fruitful.

in deficit while carbohydrate supply increases. The principle of the limiting factor seems more useful for purposes of interpretation than the ratio concept. See page 189.

Work[11] concluded that excess carbohydrate did not in itself cause unfruitfulness but might often be merely the result of accumulation because there was a deficiency of nitrogen or some other factor preventing its utilization in growth. This has been confirmed by Arthur, Guthrie, and Newell.[12]

The influence of developing fruits upon the set and growth of other fruits in later clusters was shown by Work; Murneek[13] later traced the corresponding chemical relations within the plant.

Effect of other factors. It is clear that failure to set fruit may favor vegetative growth as definitely as over-vegetation may interfere with fruit setting. Heat and drouth may blast the pistils of blossoms, or insects may injure them, nutrient supply

may be deficient, or light may be inadequate. The hereditary characters of varieties are also important in this connection.

Length of day has been shown to be important by Allard and Garner[17] and by Nightingale and his associates,[14] and Watts[15] found similar effects from temperature. The effects of light do not seem to be fully accounted for by its influence on photosynthesis, and light as well as other factors may be effective through some hormone-like mechanism. Newer developments are summarized in *Vernalization and Photoperiodism*[18]

Other plants

The balance between vegetation and reproduction in many vegetable plants is profoundly affected by such environmental factors as temperature and length of day (photoperiod) as also by the hereditary constitution of the plants. Thompson discusses these relations and gives references to the studies discussed below, several of which are listed.[16]

Premature seeding or bolting in celery grown for market is disastrous; when the crop is grown for seed, it changes the habit from biennial to annual and saves the seedsman both the time and the expense of wintering the plants. Thompson found that exposure of young plants to a temperature of 40° to 50° F. for 10 to 30 days resulted in practically all plants going prematurely to seed. See Fig. 7.6. The old idea was that checking growth by drouth, freezing, crowding, or other means caused the trouble, but Thompson tested these and found them all ineffective. There seems to be a definite period of *initiation or induction* of reproduction; after plants have been subjected to cold during that period, later exposure to drouth, lack of nutrients, or low temperature *retards* rather than *promotes* seed stalk development even though the plants cannot be brought back to normal vegetative development. The hereditary character of strains of celery is important, for stocks have been bred that are resistant to factors favoring bolting.

A number of workers, several of them associated with Thompson, have studied similar phenomena in other kinds of vegetables.[16]

Cabbage. Boswell and Miller found that premature seeding in cabbage is initiated by a two- or three-week exposure to temperatures between 32° and 50° F. Miller was able to change

Cornell University

FIG. 76. Premature seeding in celery. Blooming plants received cold treatment when young. Others did not. See text.

FIG. 77. By changing growth temperature, cabbage plants were shifted several times from vegetative to reproductive state and back again, over a period of years.

cabbage plants back and forth several times between vegetative and reproductive states. See Fig. 7.7. Boswell found the age and size of plant to be significant.

Chroboczek found that beets respond in about the same way as cabbage. See page 382.

Lettuce is not a biennial plant, and the initiation period is not clear cut. Thompson and Knott found that a temperature between 70° and 80° F. resulted in non-heading and seeding; 60° to 70° F., heading followed by seeding; 50° to 60° F., slow heading and no seeding during the period of the experimen

Onions. Storage temperatures affect the performance ot onions grown from sets, as shown by Thompson and Smith.[16f] Temperatures between 40° and 50° F. favor premature seeding, more so than either 30° to 40° or 50° to 60° F. But sets do not keep well at the higher temperature so that storage at 32° to 40° F. is desirable. Large sets go to seed more readily than small ones.

A short day retards seed stalk development, but varieties differ in this respect. Varieties commonly grown in the north require a long day for good bulb formation. The Bermuda, Grano, and other varieties of Texas bulb well under a short day.

Effects on bulbing in Ebenezer, a northern variety, are summarized thus:

Light, hours	*Temperature,* °F.	*Effect*
10	50-60	No bulbing
10	70-80	No bulbing
15	50-60	No bulbing
15	60-70	Intermediate
15	70-80	Full bulbing

Spinach. Knott[16g] found that low temperature has an important influence in initiating seed-stalk development in spinach but that light intensity and length of day favor its growth after initiation has taken place. A temperature range of 60° to 70° F. is more favorable for running to seed than either higher or lower temperature, once the plants have been exposed to the initiating temperature. These relationships are complex, and a satisfactory brief statement is not feasible. Varietal differences are important. Varieties that bolt readily go to seed quickly in early summer, sometimes before sizable vegetative growth has been made.

Plant hormones

Plant hormones, or growth-regulating substances, are materials natural to plants, or supplied artificially, which promote, retard, or influence their growth, including the balance between vegetation and reproduction. Among the more important of the synthetic materials are indole butyric acid, indole acetic acid, and naphthalene acetic acid. They have been used effectively to promote rooting of woody cuttings, to prevent dropping of tree fruits, and to improve the set of tomatoes and cucumbers in greenhouses. They have not yet been proved of important service in promoting growth of plants from seed or after transplanting, perhaps because the need is adequately met by the plant itself or from organic matter in the soil. In spite of some unwarranted enthusiasm these materials promise to find a place of permanent usefulness. Research in this field is beginning to throw light on the physiology of growth, vegetation, and reproduction.

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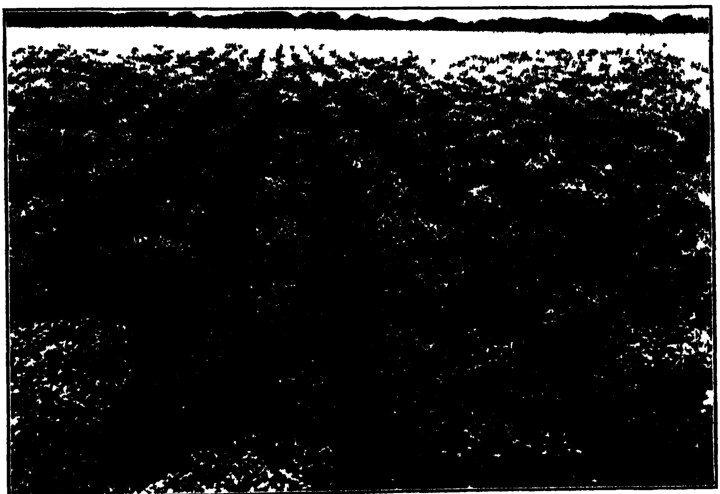
8

Good Seed

In the morning sow thy seed and in the evening withhold not thine hand.—*Ecclesiastes* 11 6

A crop of vegetables may be much poorer than the seed that is planted, but it cannot be better. Soil and weather (environment) may prevent plants from yielding the amount or the



Ferry Morse Seed Co

FIG 8 1 A field of lettuce for seed

quality that their parentage (heredity) would lead the grower to expect, but soil and weather cannot bring out of the plants better quality or higher yield than is bound up in the capabilities of the planted seed. Therefore careful selection of seed is one of the most important factors for success in gardening.

Review section on the nature of seed, page 99

The problem of procuring the best possible seed for the gardener's purpose falls into two parts: What shall he look for? How shall he get it?

WHAT TO LOOK FOR

The planter who wants good seed expects it to be (1) clean, (2) viable, (3) free from disease, and (4) true to a good name.

1. **Good seed is clean** or of high purity, that is, almost wholly free from dirt, chaff and other plant fragments, seeds of other plants, or any other foreign matter. Vegetable seeds seldom show any serious admixture of extraneous materials.

2. **Good seed is viable:** the embryo is alive and able to grow until the little plant has green leaves above ground ready to carry on the process of photosynthesis and until the little roots are in contact with the soil, ready to take up moisture and nutrients. Then it can live and grow independently of the reserves that were stored within the seed coats, and only then may the process of germination be said to be complete.

Reputable seedsmen seldom offer seed of low viability. The percentage of germination is often marked on packages. State laws more and more commonly require this marking and compliance with it. Federal law requires that stated minimum standards be met. State seed laboratories take samples from stores and make tests to check the percentages that appear on packages.

3. **Good seed is free from disease,** fungus, bacterial, or virus, which may be carried on the outside of the seed coats or within the tissues of the seed. The best assurance a buyer can have is the knowledge that seed has been grown where seed-borne disease does not prevail or that a given crop was free from disease. Plant pathologists can often detect the presence of disease by examination or by culture methods in their laboratories.

Certain diseases are controlled wholly or partly by treatment of the seed. The *outside* may be *disinfected,* usually with compounds of mercury or copper or with organic materials. Blackleg of cabbage and cauliflower is harbored within the seed coats and is controlled by hot-water treatment, time and temperature being delicately adjusted so that the fungus is killed but the embryo is not.

4. **Good seed is true to a good name.** This statement means that the little plant (embryo) bound up within the seed coats is by heredity a good representative of a variety that is good in itself and well adapted to the local environment and to the market to be served. Trueness to name is commonly much more of a problem than purity or viability. The term *type* is applied to the sum total of characters which make a plant what it is. Among these characters are: size of plant and product, color, shape, surface, edible quality, and resistance to disease. Equally important are *performance* characters, such as yield, earliness, vigor, evenness of maturity, and keeping quality. In addition, we must consider *special* characters such as adaptation to local conditions and suitability for the market to be supplied or for canning or for other purposes. Such characters as ease of pulling in sweet corn or holding bean pods off the ground are important.

Trial methods. The term *trial* refers to the planting and observing of type and performance characters of seeds. The term *test* refers to the matter of viability. Type characters are easily observed and noted in small plantings—10 to 50 feet of row. Performance characters are even more important to the grower, but it is a much bigger and more exacting job to discern differences with assurance Careful comparative trial under well-planned and uniform experimental conditions is required. There must be readings on several rows or plots of each sample (replicates), and the work should be repeated at least three seasons to even up the effect of differing weather conditions. Methods of statistical analysis are often employed to interpret the data. See page 177.

Meaning of kind, variety, strain, stock

An orderly use of terms is essential for understanding and for procuring what is wanted. Accordingly, a few words must be defined. The terms kind, variety, strain, and stock represent a horticultural classification as distinguished from botanical classification in which family, genus, and species are the categories most commonly referred to. See Work.[1]

Let us limit the word *kind* to mean all those plants which, in general usage, are accepted as a single vegetable, as tomato,

bean, or cabbage. The word kind is often carelessly misused for *variety*.

A *variety* includes those plants of a given kind which are practically alike in their important characters of plant and product. Each variety should be clearly distinguished from other varieties by one or more prominent and significant features. Examples of varieties are Golden Cross sweet corn, Topcrop bean, and Copenhagen cabbage. Names of varieties are capitalized, but names of kinds begin with lower-case or small 'etters.

A *strain* includes those plants of a given variety which possess its general characters but which differ from others of the variety in one important, or two or three minor, respects— differences not great enough to justify a new variety name. Thus, Greater Progress is an earlier, more prolific strain of Laxton Progress pea; Calwonder is an earlier and more prolific strain of the California Wonder pepper.

The difference between variety and strain is merely one of *degree* of difference. There is no clear-cut rule to indicate just how greatly different a newly bred line of plants should be to justify a new variety name. Breeders and seedsmen differ in practice. Clearly, some so-called varieties should be known as strains of a standard variety. Sometimes seedsmen rename varieties when no breeding has been done and no significant or consistent differences are discernible.

A *stock* includes all plants of the same parentage or pedigree. Seedsmen may each maintain their own lines of a variety so nearly alike that they cannot be distinguished one from another, but, since they do represent separate pedigree lines, they are distinct stocks. One seedsman may maintain two or more stocks of a single variety.

Variety and hybrid. See page 102.

Some confusion has arisen in the use of the terms variety and hybrid. These two terms belong in different categories. Variety refers to differences in characters. Hybrid refers to the process by which seed is produced. Variety belongs in the series: kind, variety, strain, stock. Contrasting terms for hybrid are non-hybrid, true-breeding, or open-pollinated. Someone asks, "Is Iochief sweet corn a variety or a hybrid?" It is a variety because its characteristics are distinct from those of other varieties.

It is a hybrid because it is the first-generation progeny from the crossing of two parent lines, in this case inbred lines. To ask "Is it a variety or a hybrid?" is like asking "Is so-and-so a hunter or a six-footer?"

The use of the term hybrid should be confined to the F_1 or first generation from a cross unless otherwise specified, for example, "an F_2 of a hybrid" as in the case of some of our tomatoes. The parents are not necessarily inbred.

Varieties of vegetables

It is clear that a grower, whether for home or market, must have a good working knowledge of the characteristics of varieties and strains of the kinds of vegetables which he wishes to plant.

Sources of information. For guidance in choice of varieties, he may consult textbooks and bulletins as well as farm-periodical articles on the subject. The grower should lose no opportunity to see different varieties, to note their major characteristics, and to learn their strong and weak points, consulting neighbors, who are likely to know what does well locally. Courses in types and varieties of vegetables are given in many colleges.

Catalogues of good seedsmen are very helpful. Some catalogues are full of "ballyhoo" and arrant sales talk, but many are informative. One soon learns to distinguish between opinion of excellence and statement of fact.

"All America Selections," announced annually, are made by vote of qualified judges. New varieties receiving awards are likely to be good, although many valuable offerings are not entered for these trials.

The discriminating seed buyer will often consult seedsmen or salesmen. These men have fine opportunity to be well informed, and many are unwilling to hurt their standing with customers by making misleading statements. Not all are like that, however. Some know little, some care less, and some are tricky. One must learn what merchants he can trust for seeds as well as for clothes or shoes.

Old and new varieties. Plant breeders, whether with seed houses, federal and state experiment stations, or individually, are constantly developing improved varieties and strains of vegetables. New names in catalogues, however, may represent mere renaming of old varieties. Some new offerings, though

distinct, may possess very little if any value. A new thing may be good in several respects but its value may be nullified by one or two weak characters such as susceptibility to disease, low yield, or inability to stand up during the marketing process.

Some people are tempted by enthusiastic trial reports or catalogue descriptions to change from old varieties to new. This is a dangerous experiment, especially for commercial plantings. Novelties may not measure up to expectations. On the other hand, many growers and many seedsmen fail to try out and evaluate new varieties and strains of merit, even after several years. Both errors are to be avoided.

HOW TO GET GOOD SEED

There are two ways to get seed for planting: to grow it or save it; and to buy it. Most people buy it.

Home growing of seed

Simple saving of seed from commercial or home plantings is of dubious value. Without definite and well-directed effort in breeding, a person's own stock is likely to deteriorate rapidly. Sometimes, an undesirable character is dominant (page 101) and becomes more conspicuous from year to year Seed-borne diseases may creep in, especially virus diseases.

Advantages. (1) One may select to suit his own growing conditions and his market. (2) He avoids the uncertainties of buying seed. (3) He becomes really intimate with his plants and varieties to the benefit not only of his breeding work but also of his culture and marketing. (4) He may find market for his surplus seed. (5) Achievement in breeding affords the finest kind of personal satisfaction; it is a fine hobby.

Disadvantages. (1) The work of selecting and crossing is very exacting; it should not be undertaken except by a person naturally patient and painstaking, willing to master the principles of plant breeding and the special skills that are required. (2) The work is likely to come when one is very busy—perhaps in harvesting and marketing. (3) The local climate may not be suitable for growing and curing seed. (4) Special equipment is often required for any but very small-scale operations.

Wind- and insect-pollinated plants such as sweet corn and the vine crops are difficult to isolate. Beans, lettuce, and tomatoes are largely self-pollinated and therefore easier to work with. Many plants are biennials, which, in most climates, must be kept over a winter to produce seed. Among these are cabbage, celery, beets, and carrots.

Buying vegetable seed

Having decided what varieties of seed are wanted, the planter wonders how to go about procuring the best possible seed. He should observe the following points.

1. Buy only from houses of *known integrity*. You cannot tell whether carrot seed is good or not by looking at it. Therefore, it is necessary to deal with a seedsman whom you can trust to give you good seed of the right variety and strain.

2. Buy from a house that *breeds its own seed* and makes a good job of it, or from a house that *purchases from good breeders*. The more intermediate hands, the greater the chance for error, the greater the cost of distribution.

3. Buy seed of *known origin*. A planter is as well entitled to know the source of his seed as to know the make of his tractor or his fertilizer. Two producing houses may offer equally good stocks of Detroit beet, but one may suit his conditions or his market or his idea, and the other may not. Even though the planter buys through a middleman, it makes a difference which stock he gets. There is strong resistance to this idea in the seed trade, especially among those who buy from seed growers and sell to planters. As planters learn to insist on knowing the origin, this resistance will break down. National advertising by wholesale producers of seed is helping in this direction.

4. For commercial plantings insist on knowing the lot number, by which seed houses identify all the lots of seed they handle. The term stock number should be reserved for stocks or pedigree lines as defined on page 114. The same house may have two or more stocks of the same variety. If one proves good for a grower, the lot number enables him to get seed of the same parentage line for the next season or to be told that it is not available. Many houses mark lot numbers on seed packages, especially in quantities for commercial planting.

5. Buy preferably from houses that maintain good *trial grounds* for the testing of seeds for trueness to type, freedom from disease, and adaptation to local conditions. Some seedsmen watch the plantings of their customers closely, but actual comparative trial ground plantings with good notetaking are of great value to both seedsman and customer.

6. Be ready to pay an *adequate price* for seed of known excellence. The proper breeding and handling of seed are costly. Cheap seed is risky, to say the least. Too many planters are price-buyers, which is a real obstacle to the seed house that tries to breed well and handle well. After all, when a pound of tomato seed will grow plants for eight or more acres, the difference between $8.00 and $16.00 per pound is not great; an extra bushel or two of very early tomatoes or an extra half ton of cannery tomatoes will more than repay it.

On the other hand, if a high price is asked, one should be sure that merit is there. There is no rule on price, and the buyer must learn to discriminate well.

Buying for home use. Points 3, 4, and 5 are less important for the home gardener than for the commercial planter. At the same time, home gardeners should learn to judge between shortcomings traceable to seed and those due to other causes. They are entitled to good seed and should insist upon it, but they should not blame the seedsman for poor results due to soil, weather, or their own carelessness.

Proved seed. Most seeds are normally viable for two or more years if stored under suitable conditions Some commercial planters buy seed a year ahead of their need so that they may make a field trial of the actual lot in their possession. Peter Henderson recommended this practice before 1900. It is good and not very costly insurance. Some seed houses do this and offer "proved seed," correctly so called. However, buyers should not confuse *proved* seed with seed which is merely *tested* for viability, and they should be sure what a seller means when he uses these terms. Proving is not very feasible with bulky seed like peas and beans or with seed of low longevity such as sweet corn, onions, and parsnips.

Non-warranty. A few seed users resent the non-warranty clause that appears on packages and in catalogues, but the thinking buyer can readily understand the necessity for such protec-

tion. As adopted by the American Seed Trade Association, it is as follows:

> The —— Company warrants to the extent of the purchase price that seeds or bulbs sold are as described on the container, within recognized tolerances. Seller gives no other or further warranty, express or implied.

In the first place, it is impossible definitely to fix the cause of every failure. A poor crop may be due to soil or climate, or error on the part of the planter, as well as to poor seed or a seedsman's error. In the second place, the seedsman is human himself, and he also faces precisely the same problems that the user faces. He must rely on someone else The value of the crop is so great compared to the price of seed that, if he were to accept all risks, the price of the seed would be beyond reason.

The best houses are extremely careful in buying and handling, and they earnestly seek to satisfy reasonable expectations.

Certified seed. Many states now offer certification service for some kinds and varieties of vegetable seeds. This service is usually conducted or at least supervised by a state department of agriculture or by an experiment station or by the two working together. Sometimes a cooperative association sponsors the enterprise.

Two points are important. First, find out just what the certificate says; and, second, find out whether its statements may be depended upon.

Certification usually covers trueness to type and freedom from certain diseases. Printed or mimeographed rules and standards are usually available for the information of the buyer.

Kinds of seed houses

The seed business is highly specialized and very complex; it now employs many highly trained experts in breeding and growing as well as on the business side.

Several jobs have to be done in providing good seed for the planter. Some seed houses engage in but one of these jobs; some, in all:

1. Breeding stock seed from which market seed is grown.
2. Testing lots of stock and market seed for germination and conducting trials for trueness to type and high performance.

3. Growing market seed from stock seed. This is often done by farmers on contract.
4. Cleaning, milling, and preparing seed for sale.
5. Transportation and storage.
6. Wholesale distribution and jobbing.
7. Selling to planters, retailing.

Some confusion prevails in the use of the term "wholesale." Some houses use it to distinguish sales to commercial planters from offerings to home and estate gardeners. Strictly, it should apply to dealings among seed producers and seed merchants.

Commission boxes and local stores. Some wholesale seed houses offer to local retail stores boxes containing an assortment of seeds, payment to be made on the basis of the quantity sold after deduction of a stated commission. There has been a tendency to condemn such seeds, but no rule is possible. Good seed and bad seed are to be found in commission boxes according to the merit of the houses that put them out. Some houses take back all unsold seeds each year and are careful about germination and trueness to type. Others are less careful—to put it mildly.

The same principle holds for local stores. Too often retailers know little about seeds and varieties, but their ignorance is partly offset by the increasing tendency to handle labeled packets of dependable houses.

The discriminating buyer may be wise to buy some items from one house and some from another. At the same time, there is much to be said for placing enough business with a single house to establish the feeling that the buyer is a regular customer, a client, who recognizes and appreciates good seeds and good service.

LONGEVITY

People often ask how long certain kinds of seeds will live. The time varies greatly. Under favorable storage conditions, some kinds retain viability 15 years or more. Under unfavorable conditions, as in warm, humid regions, seed may die in a few months. Some kinds are dependable only for a year or so.

Table 8.1 groups the kinds of vegetables according to the longevity that may be expected. Since experimental data are

meager and conditions of storage are widely variable, this information is only approximate. With favorable storage conditions seeds of group A can be kept in usable condition for two, three, or even more years.

TABLE 8.1. LONGEVITY OF VEGETABLE SEEDS

A. Dependable for one year only:

Onion	Sweet corn	Parsnip

B. Dependable for two or three years:

Asparagus	Bean	Carrot
Okra	Pea	Pepper

C. Dependable for four or five years:

Beet	Cabbage	Cauliflower
Celery	Cucumber	Eggplant
Lettuce	Muskmelon	Pumpkin
Spinach	Squash	Turnip
Watermelon	Tomato	

In general, vegetable seeds should be kept in a cool, dry place,[3] safe from vermin and insects.

When seed is to be kept in warm, humid climates, it may be packed in hermetically sealed containers. Some southern seedsmen use cool or cold storage rooms with special provision for keeping the air dry. Smaller quantities of seed may be kept in an airtight container with a little quicklime (CaO) or freshly burned wood ashes or other desiccant to absorb moisture.

For a summary of theories on the nature of the decline of viability in seeds see Clark (*N. Y. (Cornell) Sta. Memoir* 282), who gives references to original studies.

TESTING SEED

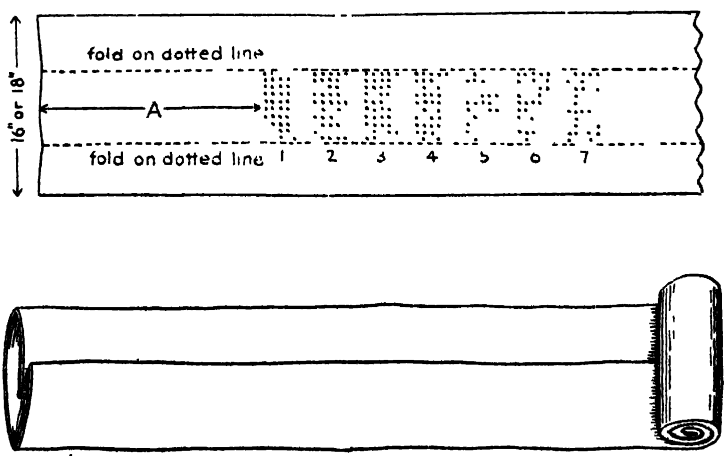
If a substantial quantity of valuable seed is over a year old or if there is doubt about its viability, it should be tested for percentage of germination. Accurate and reliable testing of seed is really a professional job. Seed laboratories have developed special equipment and special techniques for accurate control of conditions and for accurate reading of results.[4] Workers are specially trained to conduct tests and to recognize normal

Associated Seed Growers Inc

Fig 82 Testing seed by the dish method

and abnormal sprouts. Some state seed laboratories offer their services to growers.

Simple tests may be made at home, provided proper precautions are observed and the work is carefully done One way is to lay a thickness or two of blotter or cotton flannel, previously boiled to forestall fungus infection, in a dish Count out 50



Cornell University

Fig. 83. Rag-doll seed tester, for large seeds. Use cloth or paper toweling.

seeds, and cover with another bit of cloth and an overturned dish. Keep the cloths moist, and set the dish at ordinary room temperature, 65° to 75° F. Then, count seedlings as they appear and calculate the percentage; 90% is good, 75% is fair, 50% or 60% is poor. Even so, one might prefer 50% germination from a lot of seed of choice breeding to 90% from an unknown or dubious lot. In counting seedlings, discard those that are weak or abnormal in form or growth. The rag-doll method is shown in Fig. 8.3.

An even better way to test seeds is to plant 50 in a row in a box or flat of soil, providing good temperature and moisture for growth. Then, count the seedlings that actually come above ground and that establish themselves, ready to grow independently of reserves in the seed. These are said to have *completed* the process of germination and to represent viable seed. A mere counting of tiny sprouts may include some that can get that far but little farther.

GERMINATION REQUIREMENTS

When seed is planted, growth of the embryo is renewed, provided that the three requirements (1) moisture, (2) heat, and (3) oxygen are met. Light influences germination of some species, notably lettuce, but it is not essential.

1. **Moisture** is absorbed by the seed coats, resulting in swelling of seed parts and the quickening of vital activities, the beginning of growth. Some seed coats are not very permeable to water, as in asparagus, and germination may be slow for this reason.

2. **Temperature.** Life activities, in general, proceed slowly at low temperature, rapidly at higher temperatures, within limits, of course. Not much growth takes place in ordinary plants until a temperature of 40° or 45° F. is reached.

The temperature for germination varies markedly with the various kinds of vegetables. Some will not germinate at low temperatures, others not at high. Kotowski[5] found the highest percentages of germination at the temperatures indicated in Table 8.2. Note that no temperatures higher than 30° C. were tried; also, data are lacking to show whether peppers and snap beans would germinate at lower temperatures than 18° C.

TABLE 8.2. OPTIMUM TEMPERATURES FOR GERMINATION OF SEEDS

Vegetable	*Degrees Centigrade*	*Degrees Fahrenheit*	*Vegetable*	*Degrees Centigrade*	*Degrees Fahrenheit*
Lettuce	4–25	39–77	Parsley	11–18	52–65
Pea	4–18	39–65	Tomato	18–30	65–86
Radish	11–30	52 86	Eggplant	25 30	77 86
Spinach	4–8	39–46	Pepper	18 30	65–86
Beet	8–25	46–77	Cucumber	25–30	77–86
Cabbage	8	46	Muskmelon	25 30	77–86
Cauliflower	11–25	52–77	Snap bean	18–30	65 86
Onion	11–30	52–86	Lima bean	25–30	77 86
Carrot	8–18	46–65			

It was found that rate (not percentage) of germination increased generally with temperature. Holding seed under moist conditions but at low temperature did not impair their later germination.

3. **Oxygen or aeration.** Throughout its history a seed is a living thing. Life processes require energy, and that energy is supplied by respiration, in the course of which carbohydrates are broken down, by oxidation, under enzyme action, into carbon dioxide and water, with release of energy. Thus respiration requires oxygen, increasingly when germination begins and vital activities are speeded up. Oxygen must filter through the seed coats. There is plenty of it in the air, but planting in overwet soil may hinder germination because aeration is poor and the tissues within the seed cannot receive their supply of this necessary element.

COUNTS OF SEED PER OUNCE

Counts of seed per ounce or pound vary widely and have an important bearing upon decisions as to planting rates per acre or per 100 feet of row. One may be advised to plant 8 pounds of sweet corn per acre, but this may mean twice as many seeds per 100 feet of row for one variety or lot of seed as for another.

The figures in Table 8.3 are taken from various sources; they do not represent outside limits. Some actual counts have been

made, notably by Beloian (Lloyd, *Productive Vegetable Growing*, page 332), and Seelye (*Am. Soc. Hort. Sci.*, *48*:391–397, 1946).

TABLE 8.3

Vegetable	*Number of Seeds per Ounce*	*Vegetable*	*Number of Seeds per Ounce*
Asparagus	800–1,400	Parsnip	3,000–6,000
Bean, snap	60–250	Pea	50–160
Beet *	1,000–1,800	Pepper	3,000–4,500
Cabbage	6,000–8,500	Pumpkin	100–175
Cauliflower	8,000–16,000	Radish	2,100–4,500
Carrot	16,000–33,000	Rhubarb	1,000–1,400
Celery	50,000–100,000	Spinach	1,800–3,000
Cucumber	1,000–1,500	Squash, winter	100–175
Eggplant	5,000–6,500	Squash, summer	300–400
Endive	12,000–18,000	Sweet corn	110–220
Lettuce	15,000–30,000	Tomato	8,000–16,000
Muskmelon	400–1,200	Turnip	8,000–12,000
Onion	7,000–13,000	Watermelon	125–200

* Seed balls containing 1 to 3 or more actual seeds.

COATED SEED

Coated seed is seed that is covered with or imbedded in some inert material to facilitate machine dropping of a single seed at a single spot (precision planting) instead of the usual irregular distribution. The scheme is especially appropriate for irregular-shaped field-sowed seeds such as lettuce and carrots. With these, thinning is costly and an even stand is important. Two problems are not yet fully solved: (1) to be sure that each unit contains one good seed and no more, and (2) to find coating material that will take up moisture as well as the seed in its natural state.

The term *pelleted seed* is properly applied to a pellet containing more than one seed, such as is used in seeding cattle ranges, often by airplane.

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Varieties

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Several wholesale producing seed houses, such as Ferry-Morse Seed Co., Associated Seed Growers Corneli Seed Co., Northrup-King & Co., Michael-Leonard Seed Co., and F. H. Woodruff & Co., issue descriptive handbooks of vegetable varieties. These are not sales catalogues in the ordinary sense and are not for general distribution but may usually be had for libraries and class use.

The *Proc. Assoc. Official Seed Analysts* contains papers on vegetable seeds.

Seed trade papers

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9

Growing Plants for Outdoor Setting

The home garden, in order to do its most for the family, must yield vegetables during many months. Commercial growers often, though not always, find it profitable to be ready to sell their products as early as possible. Starting plants under the protection of glass cover is one of the devices for achieving early maturity and lengthening the season of harvest. Plants such as cabbage and tomatoes are also, for other reasons, started in outdoor seedbeds. Growing plants to sell can be so managed as to bring fair returns, and the income is especially welcome at the season of plant selling, a time when farm outlay far exceeds income.

Plants commonly started under glass or in outdoor seedbeds are cabbage, cauliflower, Brussels sprouts, tomatoes, eggplants, peppers, sweet potatoes, lettuce, celery, beets, muskmelons, and summer squash. Special methods for each of these groups will be taken up under crop discussions.

The same principles govern both small-scale plant growing for home garden use and larger-scale production for commercial setting or for sale. The home gardener can do things simply and easily even though a long chapter is here required to tell how and why.

Things to do. In growing early plants with the aid of glass, the farmer needs to:

1. Provide place.
2. Provide containers.
3. Provide suitable soil.
4. Take measures for control of damping off.
5. Sow the seed.
6. Look after temperature and watering.
7. Transplant the seedlings.
8. Harden the plants.

PLACES FOR GROWING PLANTS

The kitchen window affords a good place to start seedlings of vegetables. It ought to be sunny, and it ought not to freeze at night. Ordinary room temperature serves for most plants even though it occasionally drops to 50° or even 40° F. at night. Tomatoes and other warm crops should not be subjected to low temperatures. As spring advances, plants may be transplanted to a cold frame.

Cold frames

Cold frames consist of boards set up box fashion, a few inches higher on the north side than on the south. Frames are usually 71 inches wide from front to back, outside measure, to accommodate the standard 6-foot sash. See Fig. 9.1.

One of the simplest and easiest ways to make frames is to drive stakes of 2 by 2 or 2 by 4 into the ground, front and back, and nail the boards to them on the inside, 8 inches high in front and 12 inches at the back. Cross strips of 2 by 3 material, every 3 feet, center to center, are handy for putting sash on and off. Some growers make cold frames and hotbeds of concrete.

Sash. Cold frames are covered with sash, which may be bought or made in the shop. Used window sash may even be adapted for this purpose, though they do not have very good facilities for water to run off.

Sash of a light durable wood such as fir or redwood may be bought unpainted and unglazed. Standard dimensions are 3 feet by 6 feet, and there are usually three runs of 10 inch by 12 inch glass, double strength B being a suitable grade. If kept well painted and stored properly when not in use, sash will last for years—even for decades.

Glass substitutes are available and are being improved. Some consist of a wire mesh, like window screen, covered and filled with a cellulose film. They are light in weight and less breakable than glass but also less durable.

Cloth for frames. Late in the season or in mild climates, cloth may be used for cold frames instead of glass for the hardening of plants. See Fig. 9.2. The cloth may or may not be waterproofed. It may be tacked on light frames or on sash, or it may be tacked to a round pole for rolling and unrolling. If cloth is

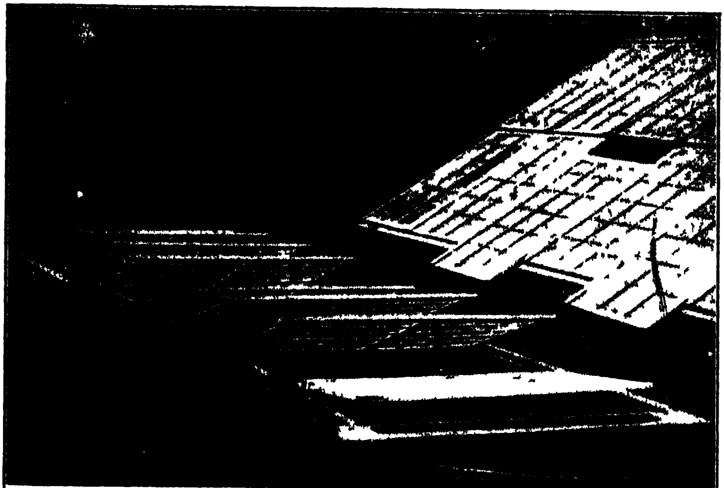


FIG. 91 Sash greenhouse and concrete cold frame

FIG. 92 Cloth-covered cold frame

placed on both sides of a frame similar to a sash, it is said to afford as full protection against frost as a glass sash

Cloth sash and even glass sash, opened for ventilation, have been known to blow all over the lot, like leaves in October. Special fasteners may be provided against this hazard

Hotbeds

Hotbeds are cold frames with provision for artificial heating. Fermenting manure is less used than formerly but is still good for farm garden purposes. A pit 18 inches or 2 feet deep is dug. It may or may not be lined with boards, and it is fitted with a top like a cold frame. Horse manure with about one-third straw is procured and piled firmly. The quantity should be considerably larger than the space to be filled as it will shrink

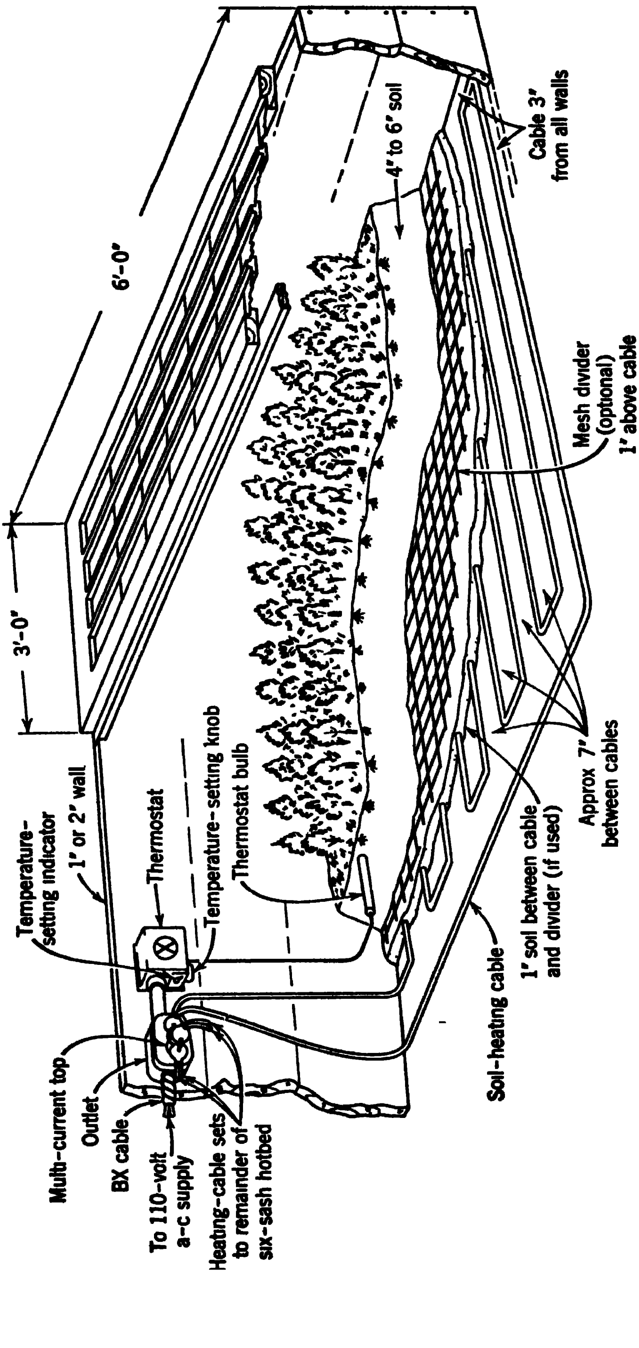
in volume. The heap is allowed to heat vigorously for, say, two or three days. It is then turned, the outside being put at the center of the new pile. This heating is a process of fermentation by organisms in the manure. When it has heated again, it is placed in the pit and firmly and evenly tramped. It will again heat strongly. When it gets down to 80° or 90° F., soil, as described for plant growing, is placed on the manure to a depth of 3 or 4 inches, and it is ready for planting. As the fermentation dies down in a few weeks, the hotbed gradually becomes a cold frame, but by this time need for heat has probably passed.

Electric heat for hotbeds is very convenient, and it is excellent for small installations. For large ones, the cost of current becomes an obstacle unless rates are very low Manufacturers and dealers furnish full directions for installation and use. See Fig. 9.3.

The outfit for electric heating is usually bought assembled ready to install. It consists of switch and fuse box, thermostat, and heating cable. The cable is of Nichrome wire of proper length and diameter, insulated and sheathed with lead. The cable must be in unit lengths as designed, for if the cable is too short it overheats; if too long, it does not heat sufficiently. To make up a set of heating cables requires some technical knowledge of electric heating One experimenter found that a one-sash bed consumed 63 kilowatt-hours in 7 weeks.

Hot-water heat is probably best for larger installations. A hot-water boiler ranging upward in size from a small garage or brooder heater is set up in headhouse, cellar, or pit. Pipes, usually 1¼ or 1½ inch, are placed at front and back of what would otherwise be a cold frame. The water circulates by gravity, cold water being heavier than hot. Thus, the high point of the pipe system should be near the top of the boiler. The pipe should fall 4 to 6 inches per 100 feet of length, all the way around. There must, of course, be an expansion tank, preferably over the boiler. For some crops, such as sweet potatoes, pipes are placed in the soil or in a chamber under the hotbed.

Flue heating. Hotbeds may be heated by means of a furnace such as youngsters sometimes make in a clay bank. Flues of



General Electric Co

FIG 93 Electrically heated hotbed

tile carry smoke and hot gases under the bed to a chimney at the far end. Wood or coal may be used for fuel. See Fig. 9.4.

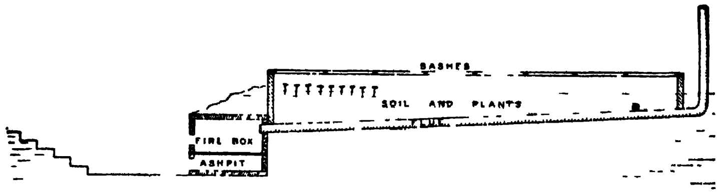


Fig 9.4. Flue-heated hotbed as used in New Jersey for sweet potatoes and other plants.

Protection. Frame yards should be in a place sheltered from cold winds and open to the sun—south of the house or barn, under a hill or in front of a windbreak. Close board fences are sometimes built.

Cold frames and hotbeds are well banked with manure or half-rotted straw to help keep them warm.

On cold nights, extra cover is needed for the little plants. On a small scale, old rugs, blankets, or quilts will do. Special waterproof mats may be bought for the purpose, or rye straw or reed mats may be made during the winter. Mats may be made from old burlap bags. Some of the largest operators throw hay or straw over the glass.

Greenhouses

After one has transplanted seedlings in hotbed or cold frame on a few windy, cloudy, chilly spring days, he wonders if there may not be a better way Greenhouses are convenient to work in, and they provide closer control of temperature and moisture than frames. They may be simple sash houses or elaborate permanent structures.

Greenhouse manufacturers will build a glass structure complete, or they will supply material, as required, for the owner to erect. Ready-cut greenhouses for plant growers may be had at reasonable figures; the price of a tractor will buy quite a sizable greenhouse, and a good one. Catalogues of greenhouse companies are valuable guides, as is *USDA Farmers' Bulletin* 1318,[2] which also gives tables for calculating heating systems.

Schools sometimes build little greenhouses, shop and agricultural departments cooperating. It must not be forgotten, how-

ever, that such a project calls for thorough study, careful planning, and prudent buying as well as good craftsmanship. Otherwise, there may be serious disappointment. Someone must look after it, too, though it is not necessary to operate it all year.

Benches are not ordinarily necessary for growing vegetable plants. Plants may grow in ground beds or flats, and pots may be set directly on the soil.

Heating of greenhouses is managed in many ways. Small houses are sometimes heated with one or two little stoves.

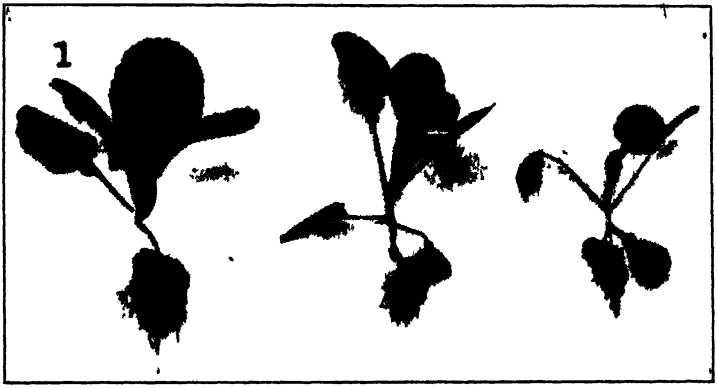


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FIG 95 Cabbage plants—good, medium, and weak

Others have flue systems as described for hotbeds. Perhaps most satisfactory is a simple piped hot-water system.

Why a greenhouse is warm. Glass structures are warmer than out-of-doors for one or more of the following reasons:

1. The glass encloses a body of air, protecting it from the currents that speedily dissipate heat. Glass is not, however, a good heat-insulator. It allows five or six times as much heat to pass by conduction as a good wall.

2. Glass permits the passage of light rays very freely. When these rays encounter surfaces within, they are partly transformed to heat radiation, and the temperature rises.

3. Provision may be made for an artificial supply of heat. The supply must be sufficient to maintain a suitable temperature in spite of constant loss to outer air. The fuel required at a given time depends upon the outdoor temperature, sunshine, and wind movement.

CONTAINERS FOR PLANTS

It is possible to grow plants entirely without containers of any sort For certain plants and under some conditions plant boxes or flats are used Also individual plants may be grown in pots of clay or paper or in plant bands of paper or wood veneer

Advantages Containers are convenient for work permitting planting and transplanting to be done at a bench and in comfort With flats or pots moisture is more readily controlled though

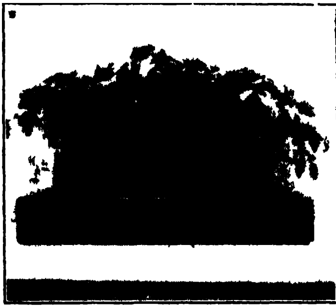

Fig 96 Good tomato plants

Fig 97 Overgrown tomato plant Should have been started later or grown more slowly

not so long retained They furnish a convenient device for transporting plants and for selling They permit field setting with minimum disturbance of root systems

Flats for repeated use should be of durable wood such as cypress The dimensions are determined by frame space flats 18 inches by 22 inches outside fitting nicely six per sash A good depth is 2½ to 3 inches For experimental or school work flats 13 inches by 18 inches are suitable, and they go ten per sash Flats half this size, 9 inches by 13 inches are sometimes used and are good for plants to sell to home gardeners For this purpose, to be used but once, they may be made of cheap thin wood, perhaps salvaged from boxes or crates—another job for the school shop

Containers are commonly used for individual plants of tomatoes and for hills of melons and squash, they are less common for cabbage, peppers, and eggplants

Clay pots are excellent, but they are best plunged in earth to prevent over-rapid evaporation from the sides.

A veneer band holds twice as much soil as a clay pot, taking the same space and leaving no surface exposed to the air to dry out They are also cheap and may be had from most makers of berry baskets

Containers of paper, either rectangular or of the shape of a clay pot, may be bought When paper containers are used, it is

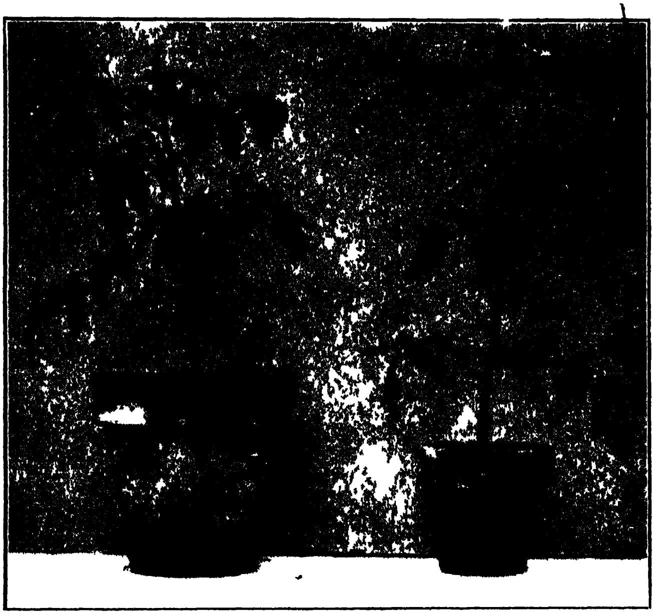

FIG. 98 Tomato plants in clay pots Plant on left is excellent, right, medium quality

necessary to watch for yellowing leaves and retarded growth, evidence of nitrogen shortage Organisms decomposing the paper take up soluble nitrogen, and growth of plants may thus be checked, just as when green-manure crops are plowed under (page 172) The application of 2 ounces of sodium nitrate per gallon of water per 25 square feet of pots will correct the trouble. Some paper pots are treated with nitrogen to forestall this difficulty.

Blocking. A good substitute for individual containers, either in flats or in beds, is the process of blocking A big butcher

knife is passed between rows of plants both ways, severing roots and making blocks of the soil. This is done about a week before plants go to the field. In the meantime, roots rebranch and plants become adjusted so that they may be set in the field with a minimum of disturbance.

SOIL FOR PLANT GROWING

Soil for the growing of early plants under glass should possess the following qualities.

Characteristics

1. **Suitable physical character.** Soil should be friable and easily worked. It should take up water readily; it should dry off quickly at the surface and yet should be fairly retentive of moisture. A sandy loam well supplied with organic matter is best.

2. **Fertility.** The soil should be well supplied with nutrients. Many fertilizer materials, however, like muriate of potash and ammonium nitrate are salts and when applied in excessive quantities will injure plants. This is referred to as soluble salt injury.

3. **Freedom from disease.** The ravages of various fungi upon young plants are grouped together as "damping off," so called because the attack usually occurs at the soil surface and plants fall over, showing water-soaked or diseased stem tissue at that point.

How to prepare soil

A good garden soil of sandy loam, well manured over a period of years, will often meet small-scale needs without further preparation except perhaps for disease control. Heating the moist soil in the kitchen oven to 180° F. and holding it there for an hour will take care of this.

Composting. Make a heap, say 4 feet wide, 3 or 4 feet high, and as long as necessary. Make alternate layers about 6 inches thick of good sandy loam soil and stable manure. Muck or peat, leaves, or sods may be substituted for part of the manure. If the manure is fresh and strawy or if sods are used, a larger amount and more time and turning will be required. If the soil

is heavy, layers of sand should be included. Stiff clay soil is of doubtful value.

Usually lime and fertilizer are not added to compost heaps, but the following will serve as a general guide

Soil should be just a little more acid than neutral, pH about 6.3 to 6.8 If soil is more acid than, say, 5 5 or 5 8, lime probably

FIG 99 Tractor-shovel, soil shredder, and conveyor save labor in handling soil for plant growing

should be added at a rate to be worked out by a teacher or county agricultural agent who makes the test. Superphosphate (18 or 20%) may be added to each layer of manure at the rate of about 2 or 3 pounds per 100 square feet. Decomposition will be hastened and nitrogen fertility built up by adding about half as much sodium nitrate to each manure layer.

The compost heap should be made a year before it is to be used; it should be near a water supply, as a moist heap de-

composes more rapidly than a dry one; and it should be turned once or twice, being cut down vertically and repiled compactly.

Where soil is to be provided in large quantities, a patch of land of suitable texture is chosen By means of a program of manuring, green manuring, fertilizing, and plowing, it may be built up in two seasons or even one so that it may be used for plant growing without the costly handling involved in composting

Many plant growers have their soil tested to reveal the content of soluble salts A solu-bridge is commonly used, determining the electrical conductivity or K-value of the soil solution Thus excessive application of fertilizer may be avoided

Putting soil through a 1-inch screen is usually sufficient to eliminate clumps of sod, stones or other coarse material and is besides, a valuable mixing process This thorough mixing or blending of materials is desirable for uniformity in plant growth Finer sifting is not necessary Some farmers use mechanical shredders for final conditioning of soil, and conveyors for handling

In northern climates soil must be stored in a place where it will not freeze or become over-moist

To minimize disease troubles and to provide good moisture control, clean sand or vermiculite (a heat-expanded mica-like material) is sometimes used to start seedlings

DISEASE CONTROL

Infection by damping-off fungi may occur from several sources: soil that is not disease free, spores drifting through the air; and contaminated flats, benches, or other equipment The following precautions should be observed as circumstances require.

1. **Avoid high soil and air moisture,** which are favorable for damping-off fungi. Useful procedures are to provide a plant-growing soil of texture as described, to water in the morning so that soil and plant surfaces will dry off promptly, and to avoid overfrequent or overheavy watering. These measures may be sufficient where plant growing is a new enterprise.

2. **Disinfect * flats, work benches, greenhouse benches, and frames** with a solution of 1 part of formalin, which is a 40% solution of formaldehyde in 50 parts of water. Flats are dipped; the solution may be sprayed on other places, care being taken that cracks are well wet. This material injures plants but it evaporates in a short time. By the same token, it affords little safeguard against reinfection.

3. **Disinfect the soil.** *Heating* to 180° F. and holding at that temperature for an hour or more serves well to destroy fungi in the soil. This may be done on a small scale by heating in pans in an oven On a larger scale, a wooden steam chamber of suitable size may be built with tight joints. Soil in flats may be stacked, using sticks as separators. Or the box may be made with drop bottom, perforated steam pipes may be built in, and soil may thus be handled in bulk. A continuous-flow flame heater has been devised for disinfecting purposes.

Electric soil heaters are widely used. They may be bought or built and are very satisfactory. Heating elements, properly designed, are built into the box, which is loaded from above and has a drop bottom for emptying

Formaldehyde † may be used to disinfect soil. Formalin (40% formaldehyde) is made up at a quart to 6 gallons of water. Soil is saturated with this solution, requiring ¾ to 2 gallons per cubic foot. Fumes are confined with wet burlap or canvas for a day or two, and then the soil is aerated well, for a few days if it is turned occasionally or for ten days if it is left in a solid bed or pile. A 6% formaldehyde dust, bought or home made, may be used at the rate of ½ pound per bushel of soil. Dust consists of 15 parts by weight of formalin mixed with 85 parts by weight of a carrier such as dried muck, powdered charcoal, or infusorial earth. Such dust should be fresh or, if stored, should be kept in airtight vessels After flats are filled, formalin (1 pint to 3 gallons of water) at the rate of a pint to 12 square feet of flat

* See footnote on page 245.

† Formaldehyde is a simple carbon compound, CH_2O, gaseous in form. It is a powerful disinfectant, suffocating to man and animals when in high concentration but not dangerous when diluted. It is also important as a material for making plastics like Bakelite, and it is believed to represent the first stage in combining CO_2 and H_2O in the process of photosynthesis which gives carbohydrates of the general basic formula $C_6H_{12}O_6$. Formalin is a solution of 40% formaldehyde gas in water.

or bed may be applied instead of other soil treatments. The flats must then be left standing for 24 to 48 hours before seed is sowed.

Mercury compounds such as bichloride of mercury (corrosive sublimate) are used for soil treatment, especially for cabbage and related kinds, but they may be injurious to other plants. Proprietary organic mercury compounds and chloropicrin are also available and should be used according to directions.

4. **Treat the seed.** Red copper oxide (cuprous oxide) is thoroughly shaken up with seed in a jar or drum so that the seed is evenly but lightly covered. A level teaspoonful per pound of seed is about the right proportion. The organic compound Arasan, as well as several organic mercury compounds, is used in the same way. When handling any of these compounds, follow directions carefully regarding quantities, and observe any precautions suggested to prevent injury.

5. **Spray or dust seedlings.** One good mixture is made by stirring 1 ounce of yellow copper oxide dust in 2 gallons of water, the suspension being kept well stirred. When applied, the spray runs down the stem of the plant and wets the soil. A pint per square foot of soil surface is ample. Mercury compounds may be used in this way, according to directions.

SOWING SEED

In filling flats it is necessary to pack the soil, not too firmly, but very evenly, giving special attention to the sides and corners. If this is neglected, the soil settles unevenly, water is poorly distributed, and plants grow irregularly.

Sowing seed is a simple operation, but questions soon arise. With flat or box all ready and filled with evenly packed soil, shall we plant in rows or broadcast? Most gardeners like to sow in rows because plants are more easily removed for transplanting and with less damage to the fine roots. It is probably better also for disease control. Rows are usually about 2 inches apart. For most kinds, 8 to 12 seeds per inch is about right. If you transplant when seedlings are quite small (1 to 1½ inches high), they may stand more thickly; if plants are to attain considerable size (3 or 4 inches high), they will need more space. Rows are marked out with the corner of a board, just shorter than the

width (or length) of the flat. This gives a smooth, wedge-shaped trench of even depth which makes for even covering and even come-up.

There are several ways to distribute the seed. Pictures tell it better than words. See Fig. 9.10. Some practice is needed before one can sow evenly and rapidly. Seeds are covered by pushing soil in with the marking stick or by drawing the thumb

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FIG. 9.10. Sowing seed from envelope in flat. Shake envelope gently lengthwise of the row.

and finger along the two sides of the row. Very small seeds like those of celery, are covered by sifting a little soil over the whole flat.

Then the flat is placed at suitable temperature and is watered. See that the flat is level, or watering will be uneven.

TEMPERATURE AND WATERING

Management of plants cannot be reduced to rigid rules. The gardener must learn to sense the growth and thrift of his plants just as a cattleman recognizes health and well-being in his animals.

Temperature and moisture are the two main factors which the plant grower controls in order to control the growth of his plants. He seeks to produce, in a reasonable length of time, plants that

are well advanced in growth, not too large for successful transplanting, and sufficiently hardened to withstand outdoor conditions but not checked, that is, not hardened so severely that they fail to begin growing immediately when set in the field.

Temperature. In general, plants grow very little at temperatures below 45° F. Cool crops will germinate slowly at 50° F. and vigorously at 60° F., but tomatoes, eggplants, peppers, cucumbers, and melons require about 70° F., see page 121. With celery, cabbage, and beet, low temperature (40° to 50° F.) for two weeks or more is likely to occasion bolting or premature seeding after the plants go to the field, see page 106. Otherwise, low temperature merely retards growth. If night temperatures cannot be kept up to 50° or 55° F., it is necessary to allow additional time. For cool crops 55° to 65° F. is a good day temperature, for warm crops like tomatoes, 10 degrees higher.

Moisture control is the grower's most effective means of managing the growth of his plants, and it is important for control

FIG. 91. The effect of different rates of watering on the growth of cabbage plants. All were transplanted at the same time and were approximately alike.

of damping off. In general it is better to water in the morning so that the plants and soil surface can dry off before night. If the weather is cool and cloudy, water lightly; if warm and bright, more water will be needed. As plants become larger, the demand is heavier. As soil surface passes from moist to dry, one can judge where extra water is needed to insure even supply

and even growth. If this is neglected, plants in some spots will be large and soft; in others small, checked in growth, and overhardened. A keen lookout must be kept to note these differences early, while they may be readily corrected. Tomatoes and lettuce are especially sensitive to moisture differences; cabbage plants are less responsive.

In flats, extra water is usually needed around the edges. In warm bright weather, some vigilance is needed to see that plants do not wilt badly.

Ventilation is chiefly significant as a means of controlling temperature. It is sometimes of value to reduce humidity or atmospheric moisture of a greenhouse or frame.

TRANSPLANTING

Plants started under glass for early market are usually transplanted once before they are set in the field. Tomatoes are sometimes shifted more than once, the first time to a spacing of 1½ by 1½ or 2 by 2 inches, then to 4 by 4 inches. See the suggested programs on page 148.

Labor efficiency. Transplanting is a long tedious job unless well organized and skillfully done. Young people with nimble fingers learn readily to do the work quickly and well. Loss of one second per plant may increase the labor cost by 20 or 25%. This principle applies to any operation that is repeated many times. Expert transplanters sometimes set 1,200 or 1,500 plants per hour; 1,000 per hour is considered a fair working basis by some plant growers.

Seedlings should be well watered the day before they are lifted. A stick or putty knife will loosen them with minimum root breakage.

Setting the plants. Some workers do not even mark out rows; with practice, the proper spacing is achieved without effort. With a dibble in the right hand, a hole is made. The seedling is picked up with the left hand and is placed in the hole. Then the dibble is used to press the soil sidewise against the root, pressure being exerted from bottom to top. See Fig. 9.13. This contact between soil and root is the most important requisite for good transplanting. Seedlings are usually set a little deeper than they grew in the previous place.

Flats may be marked with a board carrying many small pegs which make holes for the plants. The soil must be of proper texture and moisture and packed just about right in the flats. See Fig. 9.12.

When plants are shifted to ground beds in the greenhouse or in frames, workers kneel or lie on broad boards and do the work much as in flats.

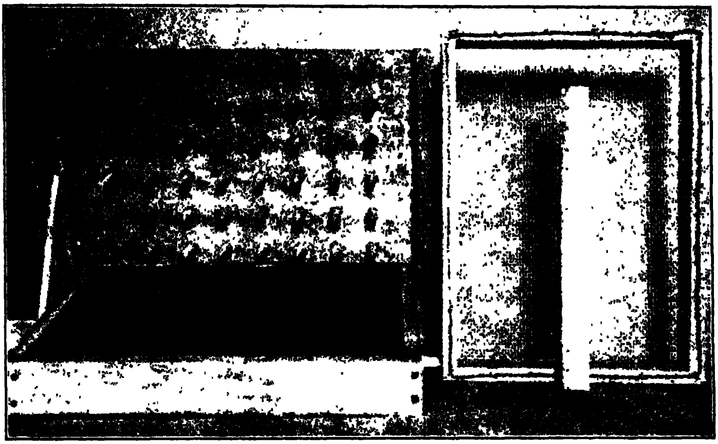

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FIG. 9.12. Flat filled and ready for sowing or transplanting. Spotting board for making holes for plants. Wire bottom flat and stick for marking and leveling.

Transplanting is usually followed immediately by watering, which helps make contact between root and soil.

The place where flats are set should be very level. Otherwise, on watering, one part will receive and absorb more moisture than another, and uneven growth will result.

In large operations mechanical conveyors or special caster-trucks are used to handle flats.

What transplanting does. Transplanting in itself does not further the growth of plants. A seedling left undisturbed in a greenhouse will mature sooner than a seedling once or twice transplanted under the same conditions. Transplanting is practiced principally to economize space under glass. The root pruning that is unavoidable does increase the branching of the root system. Such plants are better able to establish themselves

in the field because they have a denser root system in the immediate block of soil that goes with the plant. It is also true that it is easier to care for seedlings or plants in a compact area than scattered out in the field. Transplanting requires labor, and the present tendency is to treat all kinds of plants about like cabbage, shifting but once. This costs some space but saves some labor.

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FIG. 9.13. Transplanting seedlings. The soil is pressed firmly sidewise with a dibble to insure good contact with the root.

Reaction to transplanting. Some kinds of plants recover more readily after transplanting than others. Cabbage, beets, lettuce, and tomatoes are readily transplanted; plants of the cucurbits (vine crops), corn, and beans are not.

Loomis studied these plants to learn the reasons for the difference. His findings illustrate very nicely a chain of cause and effect. He learned that plants that are readily and safely transplanted are the ones whose damaged and destroyed roots are speedily replaced by new growth. This replacement in turn depends on the ability of the roots to absorb water freely. Then he found that these kinds take up water readily because there is very little suberin or corky covering on the roots whereas those that are hard to transplant successfully are distinctly suberized. This is not the whole story. The reserve of food within the plant as well as the resistance of roots to breakage may also be significant.

HARDENING

As the time approaches to take plants to their permanent place, it is necessary to harden them off so that they may withstand cold, heat, wind, and drying out when they go to the field. Hardening consists in making the conditions less favorable for rapid growth, resulting in toughening of tissues and increasing capacity to retain water. A well-hardened plant shows darker green color than an unhardened plant, and with some there is development of reddish or purplish color. Overhardening may delay renewal of growth after setting out and is to be avoided, especially with tomatoes, melons, and related plants.

Plants of the cabbage group will naturally withstand rather low temperatures, and they may be so hardened as to be unharmed at 18° or 20° F. Cauliflower, lettuce, celery, and beets are less hardy. Plants of sweet potatoes and of the tomato group cannot be hardened to resist freezing temperatures.

Keeping plants "on the dry side" is the best and most practical method of hardening. This favors development of a full fibrous root system. When plants in frames are nearly ready for field setting and wet weather occurs, it is often necessary to cover the beds to avoid an oversupply of water.

Keeping plants cool has the same effect, but it is harder to control temperature than moisture. Low-temperature hardening tends to encourage bolting or premature seeding, especially with celery, beets, and cabbage.

Hardening could also be accomplished by reducing the nutrient supply, but this would give a starved plant that would start slowly after field setting.

The nature of hardening.[9] You may wonder why a hardened plant will withstand lower temperatures than an unhardened plant. Careful research has gone far toward explaining this. Freezing damage to plants is largely a matter of withdrawal of water from the plant cells.

The water in cells contains materials in solution and so, like salt water, will not freeze at 32° F. There is also a tiny film of water around the cells, in the minute spaces between their walls. This is pure or practically pure water which freezes at temperatures only a little below 32° F. When it freezes other pure water

is withdrawn from the cells and freezes, and the water within the cells is depleted. When this process has gone far enough, the cell dies. Then, when thawing occurs, the leaves look soggy and water soaked. Soon after, if the sun comes out, the leaves become dry and brittle and are beyond recovery. Withdrawal of water from cells kills them directly and also by coagulating or precipitating proteins, which are very important in the protoplasm of the cell. It has been shown that hardy kinds of plants have great capacity for retaining moisture– the protoplasm is not readily dried out. The same is also true of hardened as compared with unhardened plants. This water-holding capacity is traced to the quantity and nature of the colloidal materials of the protoplasm.*

Thus, the hardening of plants is achieved by increasing the quantity and modifying the nature of the colloids in their cells so that they resist loss of water either by direct drying out or through freezing.

PROGRAMS FOR PLANT GROWING

Programs for the growing of early plants must necessarily be planned in the light of local climatic conditions, desired season of maturity, available equipment, and costs. Here are examples for a northern climate.

For cabbage or lettuce

Sow seed February 15 in greenhouse or hotbed.

Transplant to flats, 1½ by 1½ inch, March 1.

Keep in hotbed or greenhouse to March 15. Then move to cold frame.

Set in field April 1 to 10.

By sowing a week earlier, newly transplanted plants may go *at once* to cold frames.

* The term **colloid** describes not a *kind* of matter but a *state* of matter, a state in which the particles are exceedingly small—smaller than can be seen by the microscope but still larger than ordinary molecules. Examples of the colloidal state are jellies (colloidal gel) and butterfat in milk (emulsion). Since colloidal particles are very small, the surface area of all the particles* in, say, a cubic inch is very great and so colloids have great capacity for moisture which they retain with great tenacity.

For tomatoes, once transplanted

Sow seed March 20 in greenhouse or hotbed.

Transplant April 5 to 10, 3 by 3 inches or 4 by 4 inches or to bands or pots. Keep in mild hotbed or cold frame.

Set in field May 20 to 25

For tomatoes, twice transplanted

Sow seed March 5 in the greenhouse.

Transplant, 1½ by 1½ inches, March 20, greenhouse or hotbed.

Transplant April 15, 4 by 4 inches, bands or pots. Move to cold frame.

Set in field May 20 to 25.

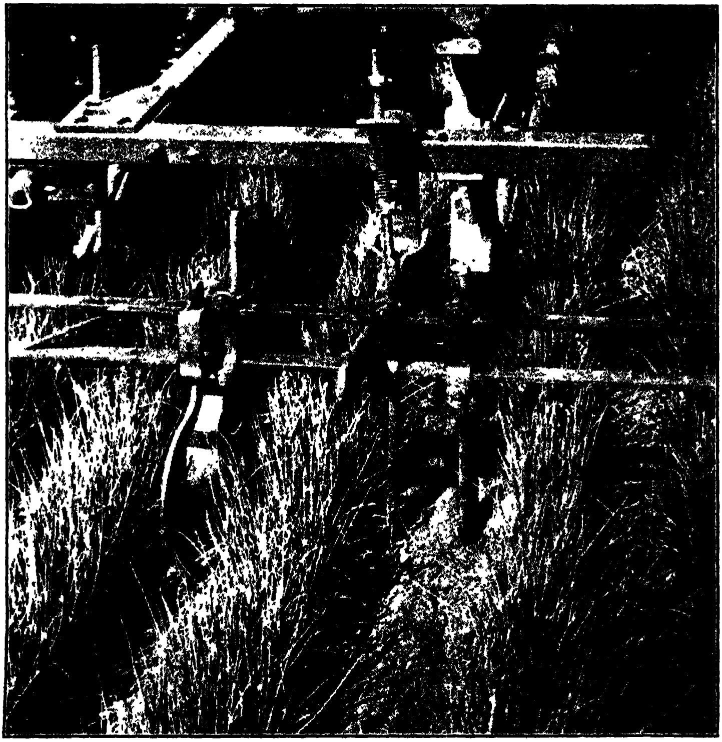
OUTDOOR SEEDBEDS

With some kinds of plants and in some climates, outdoor seedbeds are desirable even though earliness of maturity is not a requisite. It is easier to take care of young plants of cabbage, cauliflower, onions, celery, and tomatoes in small seedbeds than it is to sow the seed in the place where the crop is to grow. Land is left free longer for another market crop or for a green-manure crop. Weeds are more readily controlled, watering is cheaper and easier, insects and diseases are more effectively combated in seedbeds than in the open field. In the north, most late cabbage, celery, and cauliflower plants are grown this way, as are cannery tomatoes in the central climate zone, and transplanted onions farther south, notably in Texas.

The requirements for outdoor seedbeds are the same as for under-glass plant growing in respect to texture and fertility of soil and freedom from insects and disease. Water should be available, though many northern cabbage seedbeds are never irrigated. Where necessary, beds may be raised for drainage or they may be partly shaded.

Great care is required to be sure that the seedbed is not infested with an insect or disease that may make trouble later in the field. Think if you can of a better way to ruin a cabbage field for several years than by growing plants in clubroot-infested soil. Similar reasoning holds for nematodes, aphids, and other enemies.

Plants usually have wider spacing in seedbeds than in greenhouse, with rows 8 to 18 inches apart, according to convenience. Seed is commonly sowed too thickly in the rows, resulting in crowded, soft, spindling plants and also in waste of seed and



J. I. Case Company

FIG. 9.14. Onion plants grown in outdoor bed in south.

labor of sorting. Seed should be tested carefully for viability so that the desired stand may be reasonably assured.

BUYING PLANTS

Many farmers, especially growers of crops for processing, buy plants for field setting instead of undertaking the rather exacting job of growing them. This is good policy provided that certain requirements are met and the cost is not too high. Many market gardeners in the north grow plants to sell. Many growers in

the south produce plants by millions, especially of cabbage, tomato, and onion, to ship to northern climates. They can do this economically because outdoor beds can be used, without glass, and because labor is less costly.

As is true of seeds, both good plants and poor ones are offered for sale. Much depends on the integrity and carefulness of the plant grower There has been much dissatisfaction with southern

Campbell Soup Company

Fig 9 15 Good southern-grown tomato plants as shipped north

plants, but also many southern growers are conscientious and efficient and are doing a good job.

The buyer of plants should check on the following:

1. **Seed.** Be sure that you are getting the variety that you want and also that plants are grown from a good stock of that variety. Some farmers like to buy their own seed and furnish it to the plant grower.

2. **Insects and diseases** may prevail where plants are grown They may not be very evident when plants are received but may cause much trouble later in the season and even in later years. Aphids (plant lice), nematodes (root knot), fusaria (wilt-causing fungi), clubroot, and virus or mosaic diseases are all common.

3. **Climate and hardening.** Sometimes weather at the plant field may be warm and rainy, making it almost impossible to ship well-hardened plants. Or plants may be too old or overhardened, as when growers raise plants for earlier setting in the

south and then ship the surplus north. Such plants do not start well when set out.

4. **Packing and handling.** Plants carelessly pulled lose too many roots. If improperly packed, they may wilt or heat in transit and fine roots may die. Good plant growers loosen the plants before pulling, tie them in small bundles, put moss and paper about the roots, and pack carefully in well-ventilated crates or baskets. Others are grossly negligent.

The better southern growers will ship plants at the desired time, but the northern buyer does not know the weather that will greet them on arrival. It is hard to hold plants in good condition. The seller of plants should be held responsible for the four points mentioned above and for timely shipment, but, in fairness, he should not be blamed for mistreatment or unfavorable conditions which may occur after the plants have reached their destination. Neither should one expect the best growers to sell plants as cheaply as those who neglect important points.

Airplane and truck delivery have helped growers to adjust the time of pulling and shipping to fit planting conditions. Refrigerated storage has been very useful in keeping plants in good condition when they cannot be planted on arrival.

The state of Georgia affords a very useful certification service for plants shipped out of the state. Inspectors check plants for diseases, insects, and variety.

Pruning plants

See page 214 and reference 10.

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10

Soils and Vegetables

Most observant farmers have seen farms and fields that have declined in productiveness from year to year; they have also seen fields that have been built up to greater fertility, better crops being harvested while the land improves.

To manage soils successfully for vegetable growing:

1. Choose *good* land and land that is *suitable* for the proposed enterprise.
2. Safeguard against soil *erosion.*
3. Provide for suitable *moisture* relations.
4. See that *aeration* is adequate and that soil is in good tilth.
5. See that soil is adjusted to a degree of *acidity* or *alkalinity* such that proposed crops will grow well.
6. Be sure that the necessary *organisms* of the soil are present and that conditions are favorable for their activity
7. Maintain an adequate and properly assimilated store of *organic matter.*
8. Provide an ample supply of *nutrients* in available form.

The relations among the characteristics of soils desirable for high productivity and the means by which these characteristics are achieved are most complex and they interlock in amazing fashion; sometimes they are in conflict. For example, additions of nutrients may affect soil reaction; organic matter affects soil organisms, moisture relation, and others. For this reason a formal framework or outline cannot be followed closely.

CHOOSING SUITABLE LAND

The first step in maintaining good fertility is to choose suitable land for the kind of farming enterprise that is to be undertaken—land that is good to begin with and that can be kept in a high state of productiveness. It does not pay to fight poor

land or poorly adapted land. Realistic appraisal and thinking are essential, especially if sentimental factors such as "the old homestead" are involved. Sometimes it is cheaper to keep the old farm as a place to visit and to use other land for crop production.

Make full use of soil survey and land classification information. It is not safe to judge wholly by the price that is asked. And conflicting factors must be balanced in the light of the enterprise to be undertaken.

Depleted land with good basic qualities may sometimes be bought at a low price and brought into high productivity. Some cost is involved, and some delay in attaining good returns.

In general, the better lands for most vegetable crops are *nearly level*, or at least not too steep. Exceptions are steep lands used for peas in California and for cauliflower in the Catskill Mountains. On steep land, erosion is likely to be serious and both culture and harvesting of crops are more difficult and costly.

Stones are a nuisance and, in excess, may become a serious obstacle. But frequently they are not as bad as they look.

Serious need of artificial drainage and excessively high acidity are two defects generally more easily avoided than corrected.

Kinds of Soils for Vegetables

Soils fall naturally into two great groups: mineral soils, and organic soils, commonly called muck or peat.

Vegetables are grown in the United States on a wide variety of soils, both mineral and organic. Sandy loams doubtless predominate, especially for early and winter-grown vegetables. Late-season crops and crops for processing are likely to be grown on heavier soils, loams, silty loams, and even clay loams.

Mineral soils

Size of particles. Under one of the groupings of mineral soils, account is taken of the sizes of particles that make it up, that is, its texture, its coarseness or fineness.

Actual field soils consist of mixtures of various particle sizes. Among the names applied are sandy, sandy loam, loam, silty loam, clay loam, and clay. The first and the last are not highly desirable for vegetable production, though they may be used on

account of advantages outweighing their relatively unfavorable texture.

As we pass from lighter or coarser to heavier or finer soils, the changes in adaptation may be noted thus:

1. From easily tilled soils to soils that are hard to work.
2. From soils quickly workable after rain or irrigation to those on which operations are likely to be delayed by overwetness.
3. From very ready drainage and low water-holding capacity and retention to slow drainage and great moisture-holding ability.
4. From quickly warming to slowly warming soils, and so from early to late soils.
5. From poor to good retention of organic matter and nutrients.
6. From good to poor aeration.

These differences are traceable largely to water relations.

The coarser soils possess a relatively small total surface of particles; the finer soils, a very great surface. Table 10.1 illustrates this point. According to the last figure in this table, a single cubic foot of a heavy clay has about 4 acres of particle surface. In addition, a soil's content of colloidal matter increases its total surface. See page 148, footnote.

TABLE 10.1. SURFACE OF PARTICLES IN 1 CUBIC FOOT OF SOIL

	Square Feet
Coarse sand	8,000
Sandy loam	37,000
Loamy clay	71,000
Very fine clay	174,000

Why heavy soils are late. Even though the moisture film is very thin, obviously much water is present in fine soils, and they drain more slowly than coarse soils. Now the specific heat of water is 1.0, highest of all substances; of the mineral part of soil, it is roughly 0.2. This means that it takes five times as much heat in B.t.u.'s * to heat a pound of water 1 degree Fahrenheit as to heat a pound of soil minerals. Thus, the more water in the soil, the more slowly it warms up in the spring. By the same

* See footnote, page 63.

reasoning, a heavy soil will stay cool better in very hot weather.

Naming of mineral soils. Soils are separated into *series*, usually with geographic names, and into *types* based on size of particles. Thus, Sassafras sandy loam reveals both series and texture class, the two together being the *type* name.

For fuller discussion of properties and classification of soils see special textbooks.

Muck or peat soils *[1]

Muck soils are important in vegetable production. The principal muckland areas of the north extend in patches from New York to Minnesota, chiefly in glaciated areas where geologically recent lakes and ponds have afforded suitable places for underwater accumulation of plant material. Much of the Everglades of Florida and some other areas in that state, the Sacramento-San Joaquin River delta of California, and a few areas in Oregon, Washington, and other states consist of muck soil. Celery, lettuce, onions, potatoes, and carrots are the major crops.

The swamp soils of the United States amount to about 90,000,000 acres—about eighteen times as much land as is used for potatoes and other vegetables combined. Much of the swampland is usable muck or peat, but much is unsuitable or not economical to develop.

Origin. Muck or peat soils consist primarily of partly decomposed plant remains. A pond or lake has gradually filled up with plant material which has grown and fallen there and which has not disappeared because oxygen is not available under water for its complete decomposition. In regions where these soils exist, one can find all stages of what botanists call the *bog succession*, open water with water weeds, then semi-aquatic plants, sedges, alders, coniferous trees, and later deciduous trees such as elm, ash, and maple. See Fig. 10.1.

Properties of muck soils. Muck soils differ in their properties much more widely than is generally suspected. Considerable study has been devoted to them, notably in Minnesota, Wisconsin, Michigan, and New York.

* The terms "muck or peat" are often used almost interchangeably, usage differing by regions. When the terms are separated, muck usually refers to material more thoroughly decomposed than peat.

Following are some of the principal properties of muck soils:

1. They are composed chiefly of organic matter, combustible when dry.

2 They are dark brown to black in color.

3. They have great capacity for water and are highly retentive. This is due to the enormous internal surface incident to the cellular and colloidal nature of the material.

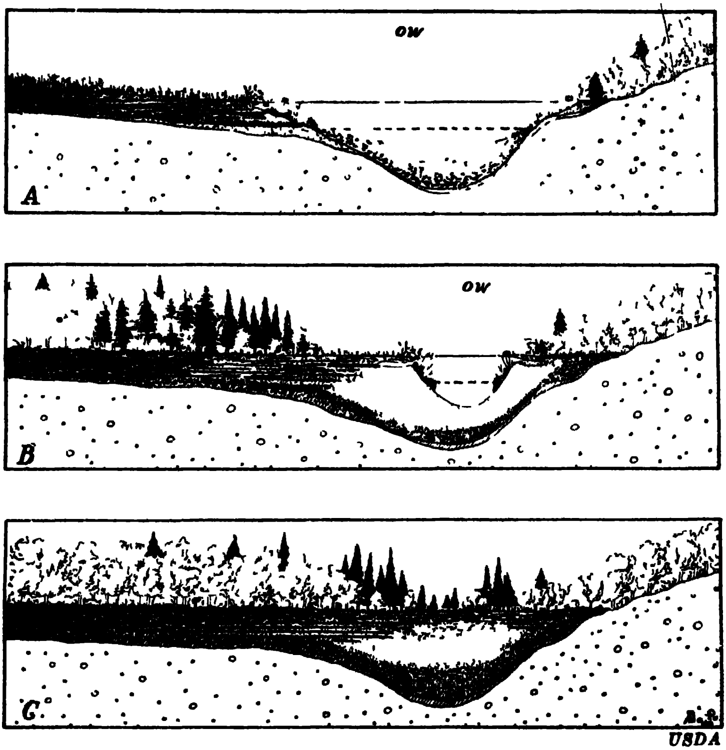

Fig 101 Formation of muck soils Note encroachment of plant growth on the pond and accumulation of partly decayed organic matter.

4. They are very friable in texture, and easily worked after rains; light in weight per unit volume, and readily wind-blown.

5. They are high in nitrogen, though in relatively unavailable form, low in phosphorus, and especially low in potash.

6. They are variable in reaction and require heavy treatments to change the level of acidity or alkalinity, that is, highly

buffered. See page 163. Most of those used for vegetables are mildly acid.

7. They are slow to warm up in the spring and are more subject to frost than upland soils, even than lowland mineral soils similarly situated.

8. They are deficient in soil organisms when newly reclaimed. Applications of stable manure readily correct this.

9. They tend to subside as organic matter is gradually oxidized.

Muckland areas usually require artificial drainage, often by open ditches, sometimes with tile. The system must be provided with adequate outlet and be so designed as to provide even drainage without lowering the water table too far. The system may be made to serve also for irrigation by providing dams to raise the water table. See soils textbooks for discussions of the principles and practices of land drainage.

Wind damage. Crops on muck soils are subject to serious damage by wind erosion, especially in their early stages of growth. If the soil is a trifle dry, great acreages may be blown clean of surface soil and of recently planted seed. After seedlings are up, whipping in the wind and the drifting of particles may bruise and ruin the tiny plants. Harmer [3] suggests several precautions:

1. *Windbreaks* of various sorts; trees or bushes are often planted for this purpose. They must be kept within bounds by deep root-pruning to prevent their excessive growth and competition with crops. Various forms of board, slat, or burlap windbreaks are also used. Windbreaks consisting of rows of oats or rye may be planted a little earlier than the crop, between every second or third row.

2. *Surface irrigation* and, in some degree, subirrigation, since moist muck does not drift readily.

3. *Compacting* the soil by rolling.

4. Addition of coarse *organic matter* as fresh manure or cover crops.

Sandy land crops not infrequently suffer by wind erosion, and the same general measures are helpful.

Frostiness of muck soils. Muck soils are generally recognized as "frosty," crops being more subject to low-temperature injury than on upland soils. The common explanation is that muck

soils are located on low lands and so receive drainage of cold air from adjoining slopes. It was noted by Bouyoucos and McCool,[4] however, that frost injury may be greater to plants on muck soil than to plants on mineral soil similarly located on low ground. Apparently some additional reason must be found.

Temperatures were taken on both soils at various levels, above and below the surface, during frosty nights. It was found that both soils lost heat to the cooler air by radiation but that the surface soil of the muck cooled off more rapidly than the mineral soil. At a depth of 6 inches, the temperature of the mineral soil fell more rapidly than that of the muck at the same depth. This indicates that the mineral soil is the better conductor of heat, that heat passes readily from the greater depths to the surface and so to the air. Thus, the air about the plants on the mineral soil does not become as cold as the air over the muck. A difference of a very few degrees in temperature is important on a critical night. It was also found that compact muck and moist muck are better conductors than loose or dry muck. These findings agree with the principles of physics. Muck soil confines a great deal of air in small spaces. Still air is an excellent nonconductor of heat. Water, usually in abundance in muck soils, is a poorer conductor than the soil minerals but better than air spaces.

These experiments suggest as control measures when frost threatens (1) wetting the muck by irrigation; (2) compacting it well before planting.

Mucks that are well decomposed, less flaky, and more compact, and also mucks with high mineral content, are less susceptible to injury of crops by frost.

EROSION CONTROL

One writer estimates that in one year a billion tons of good soil goes into the ocean and that it takes 40,000 years to make a soil 4 feet deep. Many good publications are available on soil conservation and on the causes, forms, and results of soil erosion.

Vegetable lands are highly susceptible to erosion because they usually bear clean-cultivated crops. Also, many of our vegetables are grown in regions where natural sod is uncommon,

where cultivated sod is not easily maintained, and where freezing does not intervene to stabilize the soil situation for several months. See special books and bulletins for control measures.

WATER RELATIONS

For fuller discussion of water relations see a good textbook on soils.

Drainage. Vegetable crop plants will not grow well unless soil is well drained, largely because excess water interferes with proper aeration. Ditching and tiling are costly, and, except in the case of muck lands, it is generally possible to select land that does not require special provision for drainage. For discussions of drainage planning and practice see textbooks on soils.

Water relations are affected by the texture and structure of the soil and by its organic matter, which is discussed later.

Irrigation is treated in Chapter 12.

Uniformity of growth and maturity in vegetable crops is of major significance with the high cost of labor necessitating a minimum number of pickings. Also, poor performance on even small parts of a field reduces the efficiency of the whole. Thus uniformity in water relations, drainage, moisture supply, and other factors is increasingly important. Mechanical leveling of land is practiced by many growers, usually a necessity for furrow irrigation but frequently desirable otherwise. Liberal but not excessive use of lime, fertilizer, and cover crops tends to bring the poorer parts to optimum level. Tile drainage of wet spots and contour farming also contribute in this direction.

AERATION

Aeration in soil is necessary because oxygen is requisite for the process of respiration, upon which the growth and functioning of roots depend, for the growth of beneficial soil organisms, and for the decomposition of organic matter, which is largely an oxidation process. Diffusion of nitrogen and carbon dioxide is also important.

If the drainage, physical properties, and organic content of soils are satisfactory, aeration is usually adequate.

SOIL CONDITIONERS

It has been found that certain chemicals with complex long-chain molecules improve the physical condition or structure of soils, especially of the heavier types, by tying the fine particles together into granules or aggregates. Soils so treated are easier to work, less subject to crusting, and will absorb water more readily; and also the surface will dry out more quickly after rain or irrigation. Come-up of delicate seedlings is improved. The action seems comparable to that of the natural humic compounds of thoroughly decomposed organic matter.

The new materials are currently too costly for large fields but are finding limited use in plant beds, immediately over rows of delicate seedlings, and in greenhouses and gardens.

Prominent among the soil-conditioning compounds are acrylonitriles. Krilium and Aerotil are widely advertised trade names.

The soil conditioners should be procured from reliable concerns and tried out on a small scale only, so that the grower may become familiar with their effects and uses.

SOIL REACTION

The term *reaction* as applied to soil refers to its acidity or alkalinity (basicity). It has no relation to the term "chemical reaction" save that its use probably arose by observing the reaction of litmus or some other indicator when applied to the soil.

pH is more than 7. The scale runs from 0 to 14. The figure represents the weight of free hydrogen ions present in a liter of the solution. Now that weight is exceedingly small. At pH 7, it is one ten-millionth gram (1/10,000,000); at pH 6, 1/1,000,000 gram; at pH 8, 1/100,000,000 gram. Note that pH 6 represents a larger weight and not a smaller, just as $\frac{1}{10}$ is larger than $\frac{1}{100}$. Workers soon got tired writing so many zeros, so Sørensen, an eminent Swedish scientist, suggested the use of exponents instead. Ten million is the seventh power of 10: $10{,}000{,}000 = 10^7$. Similarly, $100 = 10^2$, so the fraction $\frac{1}{100}$ may be written 10^{-2}. The minus sign makes the value the reciprocal of the same expression with a plus or unmarked exponent.

The definition of pH is "the negative logarithm or exponent of the weight in grams of free hydrogen ions in a liter of solution." Likewise, pOH 7 represents the same number of hydroxyl ions but 17 times the weight, since the atomic weight of oxygen, 16, plus the atomic weight of hydrogen, 1, is 17.

This is very simple from the standpoint of writing pH value, but one caution must be observed. The expression pH 5 represents ten times as many free hydrogen ions as pH 6 and a hundred times as many as pH 7. Thus, it will take far more lime to change a solution from pH 5 to pH 6 than from pH 6 to pH 7. This kind of a scale is called a *logarithmic* scale rather than an *arithmetical* scale.*

Buffering. The pH or active acidity of a soil does not indicate how much lime is needed for correction. Two soils of the same pH may require different quantities of lime. As fast as free H^+ ions are combined with a base and so neutralized, other H^+ ions are released. This process is much more extensive in some solutions than in others. The capacity of a solution or of a soil to resist change of reaction is called *buffering*. The *total* acidity, including both (1) *active* or pH acidity and (2) *potential* acidity, is measured by titration: by adding a base until no more H^+ ions are released and the indicator used changes color. Thus, the quantity of lime required to correct an acid situation depends

* Students should know the difference between these. Each term of an arithmetical series is found by *adding* a given value, for example: 1, 3, 5, 7, 9, 11, 13. Each term of a logarithmic series is found by *multiplying* by a given value, say 2: 1, 2, 4, 8, 16, 32, 64.

not only upon the *p*H but also upon the buffer capacity of the soil. Coarse soils and soils low in organic matter are *lightly buffered,* and so their *p*H is easily changed. Heavy, finely divided soils, mineral soils well supplied with organic matter, and muck soils are *heavily buffered* and require relatively heavy lime treatments. Various forms of buffering are discussed in soil texts.[6]

Effects of soil reaction. Soil acidity ("or alkalinity" is understood and not constantly repeated) affects the growth of plants in many ways. The effect upon plants at a given moment is governed by the *p*H or active acidity, not by the potential or titrable acidity.

1. Each kind of plant has its own range of reaction within which it does best. Watermelon is tolerant of acidity; muskmelon, cauliflower, beet, and spinach are not. Table 10.2 shows approximate ranges of several vegetables.

TABLE 10.2. ACIDITY AND ALKALINITY RANGE FOR VEGETABLE CROPS

This table must be regarded as very general. Other factors such as soil texture, colloidal content, organic matter, and moisture affect the response of plants to soil reaction. The crops listed in the first column are sensitive to soil acidity; those in the other columns, progressively tolerant. This table is based on Thompson, *Vegetable Crops* (see reference 5 in Chapter 1 and Spurway [7]).

*p*H 6.0–6.7	*p*H 5.5–6.7	*p*H 5.2–6.7	*p*H 4.8–6.5
Asparagus	Bean, snap	Carrot	Potato *
Beet	Broccoli	Lima	Watermelon
Cauliflower	Cabbage	Radish	
Muskmelon	Celery	Sweet corn	
Parsnip	Cucumber	Sweet potatoes	
Spinach	Eggplant	Tomatoes	
	Lettuce	Turnip	
	Onion		
	Pea		
	Pepper		
	Pumpkin		
	Squash		

* *p*H for potato should be about 4.8–5.4 to avoid damage from scab.

2. Reaction influences the availability of soil nutrients and also of toxic materials. Nitrogen, phosphorus, and potash are

highly available at pH 5 5–7. Aluminum toxicity is favored by extremes of acidity and alkalinity. Pettinger and Shear[6] have presented these relations graphically in a valuable chart. See Fig. 10 2

3. Reaction affects the activity of disease organisms. Club-root of cabbage and related plants is largely curbed by bringing the soil to about the neutral point.

4. Reaction influences the growth and activity of beneficial soil organisms Acidity of pH 6–7 favors the bacteria that fix nitrogen and decompose organic matter

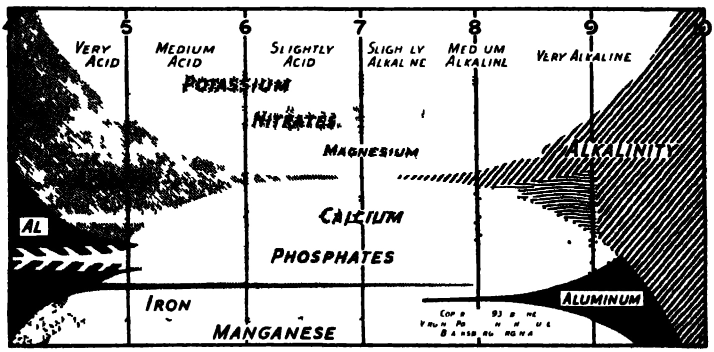

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FIG 10 2 Soil reaction chart Figures at top are pH values Areas at ends, narrowing to center, represent corresponding acidity and alkalinity values Other shaded areas *roughly* represent availability of elements corresponding to soil reaction This chart represents general relations only Factors such as moisture, minerals, organic matter, or other soil characters may change the picture materially

Two or more of these factors may interact. It is not always possible to avoid conflict between favorable and unfavorable effects of a treatment. The potato itself thrives over a rather wide pH range If, however, soil approaches neutrality, a troublesome fungus disease, scab, becomes a problem, so that the practical range is narrowed to the region between about 4.8 and 5.4. Spinach is intolerant of acid soil, and so Virginia growers who want to grow both potatoes and spinach have faced a problem. They have limed the surface soil for spinach and then have plowed deeply for potatoes This works for a while.

Associated with acidity of soils may be actual shortage of calcium, which is important as a nutrient for plants.

Measuring soil reaction. Active acidity or *p*H of soil is most accurately determined by electrode and potentiometer. The resistance of the solution to the current varies with the *p*H.

Kits for simple colorimetric measurement of soil reaction are available. They are less accurate but valuable, and must be used with an understanding of their limitations.

When a soil-reaction problem arises, it is usually advisable to call in the county agricultural agent. His equipment and his experience with the soils of the vicinity make his advice more valuable than the mere results of a test. Some farmers have studied the matter rather thoroughly and undertake successfully their own year-to-year control of acidity relations.

In general, if beets and spinach grow well, soil is not likely to be very acid. If they do not grow well, it may be due to acidity or to some other cause.

Liming the soil. Lime may be had as calcium oxide, CaO, quicklime; as calcium hydroxide, $Ca(OH)_2$, hydrated or slaked lime; or as $CaCO_3$, calcium carbonate, limestone. Fifty-six pounds of calcium oxide has the same neutralizing value as 74 pounds of calcium hydroxide or 100 pounds of calcium carbonate. Very finely ground limestone is commonly used even though calcium hydroxide is somewhat more speedily effective than limestone. If magnesium is needed, dolomitic limestone may be useed. Limestone should usually be plowed under or harrowed in.

Some fertilizers as sodium nitrate and cyanamid leave basic residues. Others as ammonium sulfate and many high-analysis fertilizers tend to make soils more acid.

Making soils more acid. Soils are sometimes higher in *p*H (more alkaline) than is best for the crops, but it is not often necessary to make soil more acid. Although the required treatments are rather costly, they are sometimes applied in commercial practice. Sulfur may be used for the purpose. It is changed by bacterial action into sulfuric acid. Aluminum sulfate is sometimes applied, or fertilizers such as ammonium sulfate which leave an acid residue in the soil.

Alkali. In some soils, especially in arid regions, certain salts accumulate in a soil to a concentration that interferes with normal growth of crop plants. The principal salts are chlorides,

sulfates, carbonates, and nitrates of sodium, potassium, calcium, and magnesium. Chlorides and sulfates are called white alkali; carbonates, black alkali. Alkali is a serious problem in some regions. It may hinder growth in three principal ways: (1) the salts themselves may be so toxic as to injure plants; (2) the soil solution may be so concentrated as to plasmolyze cells and prevent osmotic intake of water by the plants, and (3) the alkalinity or high *p*H is itself unfavorable for plants. Alkali trouble often appears in spots, sometimes caused by seepage and evaporation. Normal irrigation methods coupled with good drainage usually control alkali troubles, though over-alkaline irrigation water, changes in upward movement of soil water, and other factors may aggravate the difficulty.

SOIL ORGANISMS

Maintenance of nutrients, organic matter, and proper soil reaction usually provides sufficiently for the well-being of the organisms that are needed for a healthy soil situation. Since these organisms, mostly bacteria, are aerobic,* good drainage and aeration of the soil are required. Occasionally, when swamp soils are drained and brought into production, applications of stable manure serve to inoculate them with organisms that could not thrive in the unaerated soil.

VALUE OF ORGANIC MATTER

Plants are successfully grown without organic matter in the soil, as in pure sand cultures and also in water culture. In practical food production an adequate content of organic matter in the soil is of prime importance.

Mineral soils in good condition usually carry 1½ to 4½% organic matter and may lose 0.1 to 0.3% in a year.

The principal sources of organic matter are animal manures, crop residues, and green-manure crops.

Decaying organic matter serves several useful functions in the soil.[14]

* Aerobic, thriving in the presence of oxygen; anaerobic, living in the absence of oxygen.

1. *Organic matter supports organisms.* A good soil is not a dead thing; rather, it is a veritable beehive of activity for countless organisms: bacteria, fungi, and low animal forms. These organisms change plant nutrients from unavailable forms to available; some reverse the process; and some actually gather nitrogen from the air, fixing it in the soil so that it may be used by growing plants. For these organisms to grow and do their work, they must be nourished, like other living things. This nourishment they find largely in the organic matter of the soil.

2. *Organic matter improves the texture of the soil,* rendering it more friable, that is, more readily worked, less subject to baking and crusting, and less likely to form hard clods if plowed when just a little too wet or too dry. Drainage is improved.

3. *Organic matter increases the retention of moisture and nutrients,* since it is composed of remains of plant cells and includes a good deal of colloidal material. Since the surface of particles is enormous, it is sponge-like in possessing great water-holding capacity.

4. *Organic matter favors aeration,* allowing freer passage of air through the soil. The oxygen of the air is necessary both for the organisms of the soil and for the roots of the plants that grow in it. Oxygen is essential for the process of respiration, which is common to both plants and animals and which yields the energy or power necessary for growth.

5. *Organic matter, in decomposing, gives off carbon dioxide* (CO_2), a mild acid which is an important solvent in soils, rendering minerals more available to plants.

Effect of root foraging. In addition, green-manure crops render nutrients more available because their roots often reach far into the subsoil, gathering mineral material and making it part of their bodies. Then, when the crop is plowed under, this material is in the upper soil where the young plants of the next crop can readily reach it.

Loss of organic matter. Under farming conditions the organic-matter content of the soil usually declines, largely by oxidation, a process comparable to the burning of fuel. Oxidation goes on more rapidly in hot climates and in regions where the soil is not frozen in winter.

GREEN MANURING

One of the ways to check destructive soil erosion and to replenish organic matter in the soil is to plant green manure or cover crops [14,15] as soon as the harvest is removed. Sometimes seed is sown before harvest, between the rows of the market crop, so that the soil may not be bare even for a few weeks.

Too many farmers feel that they cannot give up land for the production of organic matter to plow into the soil. But organic matter is important to insure reasonable return from other treatments—fertilizer, water, and seed.

Terms. The terms *green-manure crop, cover crop,* and *catch crop* all mean about the same thing, but the emphasis is on different phases of their usefulness.

The word *humus* is often used loosely for the better term, *organic matter,* most of it of plant origin, found in various stages of decomposition. More exactly, humus refers to a somewhat indefinite group of chemical substances dark in color, rather stable in character, colloidal in nature, and resulting from rather advanced decomposition of organic matter.

Choice of crops for green manuring. Of the countless kinds of plants that nature has given us, certain ones have proved especially suitable for green-manure purposes. The entire list is long, but great regional differences in climate and soil limit the choice for a given place to a rather small number.

The following characteristics may be sought in choosing among the various green-manure plants. No one crop will be ideal in all respects; the farmer must strike a practical balance among the various possibilities. The experience and customs of the neighborhood furnish good guidance.

1. *It should produce an abundance of organic matter* to be plowed under. This is a major consideration. Nitrogen can be bought, but humus-making materials are scarce and costly, not only to buy but also to handle.

2. *It should have a heavy, deep, and widespread root system* for efficiency in absorbing water and nutrients. Roots may yield a fourth to a third as much organic matter as the tops.

3. *Growth should be rapid* so that the crop will take up a minimum of time that may be needed for other crops.

4. *The plant should be hardy* to such unfavorable conditions as it is likely to encounter during its period of growth: heat and drouth in summer or frost through the winter.

5. *The nitrogen-gathering capacity* of the legumes is highly desirable, provided that there is not too great sacrifice of other advantages. Heavy yield of organic matter, as pointed out above, may outweigh the disadvantage of a plant's being a non-legume. A leguminous crop may add as much as 100 to 200 pounds of new nitrogen to an acre of soil if fully grown and plowed under in its entirety.

6. *Seed should be cheap, germination vigorous, and culture easy.*

Non-leguminous green-manure crops. *Rye* is probably the most valuable and most widely used green-manure crop, country wide. It is hardy enough to survive winters practically anywhere in the United States; it makes heavy and rapid growth; and it utilizes odds and ends of growing weather during the winter. Thus it may be planted late and plowed under early. Experiments by Wessels and Hartman [15] on Long Island showed rye to be definitely superior to other green-manure crops as measured by increased yield of succeeding vegetable crops. *Winter vetch* is sometimes sowed with it to add the benefits of a legume, but the seed is expensive and results are not very significant. *Barley* and *oats* are similarly used, but they do not survive severe winters.

Italian rye-grass has come into use, but it must be sowed earlier than rye.

Leguminous green-manure crops. With the legumes, lime and inoculation requirements must not be forgotten.

Crimson clover, a winter annual, and *mammoth red clover*, a biennial, planted at the last cultivation, give good results.

Biennial white sweet clover, *soybeans*, and *cowpeas* require fairly long growing seasons, but they make heavy growth and are widely used.

Sesbania, *crotalaria*, and *lespedeza* have proved valuable in the south.

Alfalfa is a great forage crop and a great soil improver with its deep, wide root system and its nitrogen-gathering capacity. It is a valuable asset to the many farmers who produce both animals and vegetables. It may be sowed in midsummer and

grown through the current and following season, or sown in spring and plowed under the second midsummer, with good results. It takes more time than most crops, but it is widely used in rotation with vegetables, especially in the southwest. Alfalfa is grown for three or four successive years, and vegetable crops for market are planted for a similar period.

For details on adaptation, requirements, and culture methods for these crops, see the bulletins[14,15] listed at the end of the chapter and publications of your own and neighboring states.

Other sources of organic matter. Careful conservation of residues of market crops is an important means of maintaining humus in the soil. These residues are often as heavy as a good cover crop. Their value is commonly wasted by letting them dry up and blow away. Prompt plowing under of pea vines, bean, corn, cabbage, and even tomato and melon plants will result in material improvement of the soil.

If the farm enterprise embraces animal production, plantings of forage crops may be managed with an eye to increasing the organic-matter content of the soil.

Sawdust and shavings[18] are often available for the hauling. They have been shown to be harmless to soil and plants if they are accompanied with liberal nitrogen fertilization. They may be used directly or as a mulch between rows of crops, applied to a thickness of 1 to 3 inches. Farmers making extensive use of such materials conserve labor with special removable truck bodies, mechanical loaders, and spreaders.

Management of green-manure crops. Green-manure crops merit the best management that can be given them. This often means increased care and thought rather than increased expense.

1. *Rate of seeding.* A thick stand of plants is desirable to increase the total dry matter to be plowed under, at least with most plants, and especially if the time during which the crop can grow is short.

2. *The seedbed should be well prepared* to insure a maximum stand with minimum quantity of seed.

3. *Commercial fertilizer* may often be used to great advantage with green-manure crops. The farmer may hesitate to spend money for nutrients for a crop that he will not market, but the nutrients will not be lost, for they will be plowed under ready for the succeeding market crop. His extra reward will come in

increased tonnage of organic matter added to the soil. Nitrogen is especially effective in this role.

4. *Allowing the plants to grow to large size* is the simplest and easiest way to increase the amount of organic matter plowed under. At a late stage of growth, plant material is manufactured very rapidly, and a week or two of time may increase the tonnage to be added to the soil by 25 to 50%. On the other hand, large plants draw very heavily upon the moisture of the soil, depleting the supply required for rapid decay of the material and leaving the soil too dry for the best starting of the succeeding crop. Moreover, the nitrogen-deficit problem described below becomes more serious as the plants are larger. Thus the farmer faces a dilemma that can be solved only by his own good judgment in the light of the time available and the temperature and moisture supply that are to be expected. The objections, however, can be minimized, and the effort is well rewarded.

5. *Plowing under.* Powerful modern tractors and deep cutting plows have solved many of the problems, formerly serious, involved in getting green-manure material into the soil. Ample power and the proper adjustment of the plow to make a clean furrow slice will leave no material above the surface to interfere with harrowing and planting. The slice should be at an angle rather than completely turned over, so that soil will be in contact with soil, avoiding a full blanket of plant substance. A coulter on the plow is a great help; a chain adjusted to drag the plants down toward the open furrow is another aid. If the crop is very large or hard to cover, it may be disced down, perhaps twice, once in each direction, before plowing.

A roller or an implement such as the cultipacker will help compact soil and green matter so that moisture conditions may be more favorable for decomposition.

Nitrogen deficit. When plant material is plowed into a normal soil, with a reasonable moisture content, soil organisms, mostly bacteria, begin decomposing it at once. These organisms live and grow and multiply prodigiously, using energy from the newly found organic matter, and also taking up much of its nitrogen. Thus the succeeding crop, if planted at once, may suffer from a shortage of available nitrogen, resulting in yellowish foliage and retarded growth. The nitrogen taken up by the organisms is not lost but becomes available when their work is

done and they die. The situation is readily corrected by applying nitrogen to the cover crop just before it is plowed down. This procedure not only meets the difficulty but it actually promotes the growth and activity of the organisms and hastens the incorporation of the new organic material in the soil complex.

Carbon-nitrogen ratio. Careful studies have shown that the ratio * of carbon to nitrogen in organic matter of soil, on a dry-weight basis, may range from 10:1 to 20:1. It has been found that, if the ratio is wider than 15:1, growing plants are likely to be affected by a shortage of available nitrogen, and the addition of nitrogen is indicated.

Applications of 20 to 60 pounds per acre of nitrogen as ammonium nitrate, or calcium cyanamide, are usually adequate as nitrogen supplements to green-manure crops. The material may be applied shortly before plowing. If supplied earlier it will serve this purpose and will tend to increase the growth of the cover crop as well.

NUTRIENTS IN SOILS

Plants depend heavily upon the soil for their well-being and growth. The relationship between plant and soil is complicated. The plant depends upon the soil for water and for mineral nutrients; it is affected by the reaction of the soil, by the presence of toxic materials, and by insects and diseases that may harbor there. The amounts present and the availability of both nutrients and water are influenced by the original composition of the soil, by aeration and drainage, by soil reaction, by the organisms present, and by its content of organic matter or humus. Thus many interactions among these and other factors might be traced. No simple diagram could tell the story.

Nutrients

The principal nutrients † added to the soil are nitrogen, phosphorus, and potash. Many other chemical elements are necessary for plant growth; some of them are required in very

* To the teacher: Be sure that the class understands the ratio concept and its relation to quantities and to the quantity concept. Percentage is a ratio concept.

† Plant scientists call the materials for plant growth (aside from water) that are derived from the soil *nutrients*; the products of photosynthesis

small quantities and are usually present or are added in ordinary soil amendments. Among these are sulfur, calcium, and iron. Deficiencies of boron, manganese, magnesium, copper, molybdenum, and zinc are not uncommon, and, when shortage occurs, additions are very important. Symptoms of deficiencies are becoming known through careful study. Such books as *Hunger Signs in Crops* [10] illustrate many of these symptoms.

Availability. Plants may suffer through unavailability of nutrients in the soil as well as from actual absence or shortage. Plants are able to use elements present in some chemical compounds but not in others, and they may actually be injured by still other combinations; thus, although iron is essential, in ferrous * form it is injurious, but in ferric form, acceptable. Availability is an important consideration in choosing fertilizers. It is greatly affected by the chemical reactions that take place in the soil directly or through the action of organisms, chiefly bacteria.

Nutrients may be unavailable because they are insoluble in water or the mild acids of the soil or because they are combined chemically with other ions which the plant cannot use, or because they are firmly held on the surfaces of soil particles (adsorption).

Factors such as drainage, organic matter, and reaction have important bearing upon availability.

Nitrification is a bacterial process carried on by organisms in the soil, by which ammonia (NH_3) is oxidized to nitrite form (NO_2), and then to nitrate (NO_3). Nitrates are taken up by plants and hydrolyzed into more complex substances: into *amino acids* (groups carrying C, H, and NH_2), and then into *proteins,* in which form most of the nitrogen of plants exists. When the plant tissue dies and decays, proteins break down to amino acids and then to ammonia which so becomes available for nitrification. This whole series of processes is called *the nitrogen cycle.*

(carbohydrates) they call *food.* This is an arbitrary distinction but fairly useful, nor is it so hard and fast that it is a crime to speak of, say, "phosphorus feeding of plants."

* Ferrous refers to compounds of bivalent iron, such as FeO; ferric, to iron of higher valence, usually trivalent, as Fe_2O_3.

Most plants use the nitrate form of nitrogen more readily than the ammonia form. Usually the ammonia must be converted to nitrate before the plant can take it up. This nitrification occurs at a slow rate in cold soils. Therefore, sodium nitrate will be a better side-dressing material for early spring use than ammonium sulfate. Ammonium nitrate is now widely used.

Fixation. Sometimes it is suspected that a soil needs phosphorus to make a good crop. An experiment is set up to test the effect of, say, 20, 40, and 60 pounds of P_2O_5, phosphorus pentoxide, per acre. Unexpectedly, there may be no gain from even the high treatment. One might easily conclude that a shortage of something else must have caused the trouble. But somebody says, "Let's try 80 and 100 pounds," and a significant increase in yield is recorded. Research has shown that in some cases like this there are chemical compounds in the soil which react with the added element and render it unavailable. Then, as soon as that reaction requirement is satisfied, the further quantities are available for the plant, and improved growth follows. This phenomenon is called *fixation*. This is just one example of the many puzzles that farmers and research workers have to solve.

How to judge needs

Analysis of soil. It is commonly assumed that an agricultural chemist can analyze samples of soil and, by considering shortages so revealed, tell just what is needed to make crops grow well. In theory also one should be able to analyze a crop to determine what nutrients were removed and then to maintain fertility by putting back an equivalent quantity. Actually, it is not so simple as that.

An analysis may be useful to reveal shortages, but it may also show an ample quantity of all needed elements even though plants do not thrive and do actually respond to additions of one or more nutrients. The nutrients may be present in a chemical form which the plant cannot absorb, or some other condition may interfere with their utilization.

Quick tests. Full laboratory analysis of a soil is a long and costly process. Considerable progress has been made in the development of quick tests which may be applied to the soil,[8] and in addition tissue tests have been devised to reveal defi-

ciencies by observing reactions of plant material. In the hands of those who are familiar with their use and interpretation, these tests are valuable within limits, but there is danger of placing too much reliance on them, and occasionally unscrupulous salesmen have misused them.

Experiments. A more useful method of appraising fertilizer needs is by the conduct of well-planned experiments. This is

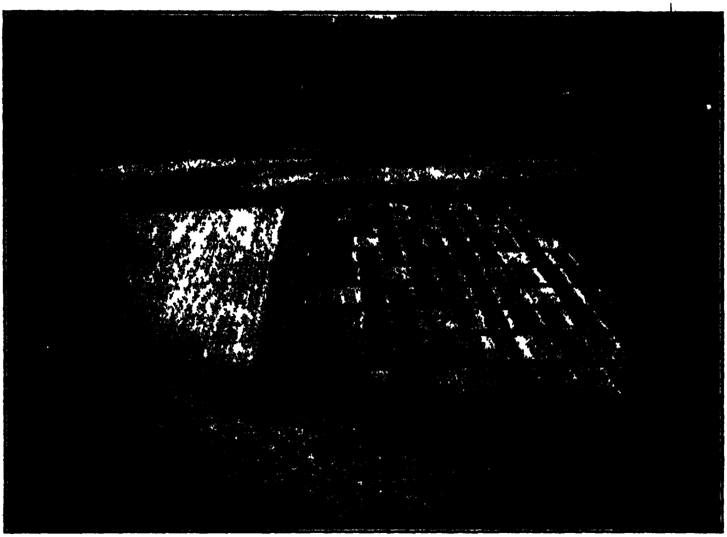

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FIG. 103 Fertilizer and rotation experiments. An elaborate layout of plots, with many treatments and replications.

very laborious and costly. There are many kinds of soil, many crops, and many possible treatments to be tried out. Experiments must be carried for several years to allow for the effects of variable weather. Plots must be *replicated* several times to iron out irregularities of soil in the experimental field and to give enough observations to make sure that differences in results really mean something; that is, that the differences are *significant*. But, by this long hard process, much has been learned about the needs of crops on the soil where the experiments were made, and light is also thrown on needs in other situations. Of course, much care must be exercised in applying such findings in other places.

STATISTICAL ANALYSIS AND DESIGN OF EXPERIMENTS

Anyone who reads bulletins or papers reporting results of research should be able to understand in an elementary way the indications as to whether these results are significant or not—that is, how dependable they are.

The following statements are general and oversimplified and do not take the place of a full discussion.

Statistical analysis is a system of mathematical treatment of data from observations and experiments that enables the worker and the reader to judge more or less accurately whether the differences are due merely to chance variation or whether they are due to differences in the genetic and environmental factors involved. Environmental factors are presumably governed by the experimental treatments that have been applied. However, not all factors can be controlled, and certain factors may be overlooked. The same principle applies to studies of hereditary factors, varieties, and strains of crop plants.

In general, statistical analysis is based on the assumption that sampling is adequate and representative. Utmost care must be exercised to see that this is true.

Then come two other foundation statements that might be called axioms:

1. The larger the number of samples measured or observed or the greater the number of replicate plots in an experiment, the more dependable the result This value is called *frequency, f.*
2. The more uniform the readings from a series of samples or replicates, the more dependable the results. The greater the *deviation* (*d*) from the mean or average, the *less* reliable the results.

To increase the probability of achieving meaningful results, that is to insure (*a*) representative sampling, (*b*) adequate number of readings, and (*c*) minimum variation in readings, the methods of experimental design have been highly developed, involving number and arrangement of plots and other factors.

There are three ways of indicating the significance of data.

1. A difference marked by two stars or asterisks (**) means that statistical analysis has shown the difference to be *highly significant;* that the odds are 99:1 or greater, that the difference

is *not* merely due to chance. The single star (*) means that the difference is *significant*, with odds of at least 19:1 that the difference is not due to chance. These odds are sometimes expressed as "at the 1% level" or "at the 5% level," respectively.

2. Sometimes L.S.D., least significant difference, is stated either for odds of 99:1 or of 19:1. Presumably, if the difference between two averages is greater than the L.S.D. value, the dif-

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FIG 104 Tomato fertilizer experiment Left, 1,500 pounds per acre, 5-8-13 Right, no fertilizer Guard row in center

ference is highly significant if at the 1% level or significant if at the 5% level. The L.S.D. test is subject to certain limitations since, as a single value, it is not equally applicable to all possible comparisons.

Example. Suppose you are comparing the yields of two sets of replicated tomato plots. One set gives an average of 15.1 tons per acre, and the other, 15.2 T/A. Anyone would say there was no meaningful or significant difference. If one average was 15 T/A and the other 30 T/A, one would be fairly sure the difference was significant. But if the averages were 22 and 26 T/A, what would you say?

The L.S.D. calculation gives you the difference that is required before you can assume that the response was not due to chance variation and was presumably due to the treatment

applied. Thus if 500, 1,000, and 1,500 pounds of fertilizer produce yields of 15, 20, and 21 tons per acre, respectively, and the L.S.D. is found to be 2.5 T/A, you may then assume that, were the experiment repeated under the same conditions as before, both the 1,000-pound and 1,500-pound rates would be significantly better than the 500-pound rate but that the probability is very remote that there would be significant benefit in increasing the rate from 1,000 to 1,500 pounds per acre.

3. A summary of the statistical calculations may be given to tell the story of significance.

Practical significance. It should be borne in mind that statistical significance and practical significance are two different things. A difference between 20 T/A and 21 T/A may be statistically significant in a given experiment but, considering variations in weather, soil, management, and cost factors, it would not be practical to recommend a change in, say, fertilizer treatment, merely because it is statistically significant.

A publication reporting experiments should always mention forms of experimental design, number of replicates, and method of statistical analysis even though it is written for extension purposes. Otherwise, readers may make a wrong interpretation or may wrongly assume that these valuable research tools were not employed.

Those who wish to plan experiments soundly and to apply the methods of statistical analysis should take courses in the subject or read suitable books. The following are among the simpler and clearer books available:

Peterson, D. D. *Statistical Technique in Agricultural Research.* McGraw-Hill, 1939.

Love, H. H. *Experimental Methods in Agricultural Research.* Univ. of Puerto Rico Expt. Sta. (Río Piedras). 1943.

Application of findings. A skillful adviser such as a county agricultural agent uses *all these resources* in making a fertilizer recommendation, calling also upon his knowledge of soils and crops in the area and mixing in quite a dash of common sense. Nor does he forget the economic factors.

The well-trained farmer does the same thing, utilizing the things he reads, the things he learns from other growers, and the advice of a county agent or extension specialist, and then making his own decisions.

COMMERCIAL FERTILIZERS

The shortages of nutrient elements in a given soil for a given crop are corrected by the application of commercial fertilizers and animal manures. There are on the market some dozens of chemical compounds which carry one, two, or three of the principal nutrient elements, nitrogen, phosphorus, or potash, in form suitable to serve as nutrients for plants.

Nitrogen content in fertilizers is now stated in terms of the element (N) but was formerly indicated as ammonia (NH_3). Principal present-day sources are as follows:

Sodium nitrate, $NaNO_3$, carries about 16% N, immediately available to plants, and it leaves a residue with slightly alkaline effect on soil. It is mined in Chile, and it is manufactured from the nitrogen of the air.

Ammonium nitrate, NH_4NO_3, contains about 33% N, in both ammonia and nitrate forms. Thus the nitrate is immediately available to plants, and the ammonia must undergo the bacterial process of nitrification, which changes it to nitrate. This material is cheaper per unit of nitrogen than sodium nitrate.

Calnitro, calurea, urea, ammonium sulfate, and *calcium cyanamide* carry nitrogen in various forms.

Pure ammonia, NH_3, which is liquid under pressure in cylinders and a gas when released, is sometimes fed into irrigation water as it runs into the furrows. It is so dissolved and finds its way into the soil with little loss. It is also fed into the soil by means of suitable equipment.

Phosphorus content in fertilizers is stated as phosphorus pentoxide, P_2O_5. The usual source is raw phosphate rock, calcium phosphate $Ca_3(PO_4)_2$, abundant in Florida, Tennessee, and other parts of the United States.

Superphosphate, $CaH_4(PO_4)_2$, is phosphate rock treated with sulfuric acid to render the phosphorus available or soluble. It carries 16 to 20% phosphoric acid. *Triple superphosphate* is very highly concentrated, up to 42% P_2O_5. Phosphorus in these forms is immediately available. In the soil, it soon reverts to a dicalcic or tricalcic form which is not readily leached away and which becomes available slowly.

Many compounds carry two elements; ammophos, for exam-

ple, supplies both nitrogen and phosphorus. It is available in 11–48–0 (percentage of N and P_2O_5) and 16–20–0 forms.

Potassium, K, is stated as potash, K_2O. The principal source is ancient lake deposits in the southwestern states.

Potassium chloride, KCl, or muriate of potash, is widely used. It carries around 50 to 60% of potash. *Potassium sulfate* is less common than *muriate*.

Nitrophoska contains all three major elements.

Fertilizer mixtures. Fertilizers are usually bought in complete mixtures. Nitrogen side dressing and the use of phosphorus to supplement the nutrients of animal manures afford occasion to buy the separate materials. Availability of open-formula goods and of an adequate variety of mixtures renders home mixing less necessary than in former years, although some large users find it profitable.

Fertilizer notation. The content of the three major nutrients in a fertilizer is expressed in percentage of nitrogen, phosphoric acid, and potash. A 5–10–5 fertilizer carries 100 pounds, 200 pounds, and 100 pounds, respectively, in each ton. These figures are called the *analysis* of a fertilizer. They are based on *available,* not total, material, but they do not tell what form it is in or what minor nutrients are present.

Fertilizer companies and experiment-station workers have agreed that a mixture may not be designated *high analysis* unless it carries at least 20 units of nutrients; that is, a 5–10–5 is the lowest 1–2–1 ratio that would meet the standard. There is no point in making and selling a 4–8–4.

The wide variety of new fertilizer materials, some of high concentration, have made it feasible to mix goods of very high analysis. For this reason, it has proved convenient to designate several analyses by a single *ratio*. A 1–2–1 ratio would be met by using a 5–10–5, an 8–16–8 or a 10–20–10. A ton of the first would be equaled by 1,250 pounds of the second or 1,000 pounds of the third. In general, the high concentrations mean economy in mixing cost, freight, bags, and handling.

The user of fertilizer is concerned not only with content of nutrients but with form as well. The *formula* of a fertilizer tells just what ingredients have entered the mixture and how much of each. Table 10.3 shows an example of an 8–16–16 fertilizer with calculation of analysis.

TABLE 10.3. FORMULA FOR A FERTILIZER OF 8-16-16 ANALYSIS

Pounds of Materials		Pounds of Nutrients (approximately) N	P_2O_5	K_2O
200	Ammonia solution 2A, 40.6%	81		
387	Ammonium sulfate, 20%	77		
137	Superphosphate, 19.5%		27	
640	Triple superphosphate, 46%		294	
530	Potassium chloride, 61%			320
6	Fertilizer borate			
100	Conditioner (sand, poultry manure)			
1	Detergent			
2,001		158	321	320

State laws require that bags be tagged to show the pounds of fertilizer, the brand name, the name and address of the manufacturer or dealer, and also the guaranteed percentage of nitrogen, available phosphoric acid, soluble potash, and content of minor elements. State departments of agriculture usually sample and analyze fertilizers offered for sale and warn or prosecute any concerns that do not fulfill the guarantee.

Open formula. Fertilizer tags do not usually give the formula. It is desirable for the user to know the formula, but it is not especially convenient for the manufacturer to supply it, as it involves frequent changes in tags as market prices of materials fluctuate. Some companies would prefer not to reveal their formulas, either for competitive reasons or because they use low-grade materials. Some concerns, notably farmer cooperatives, now put up *open* or *public-formula* goods.

Minor nutrients. Many fertilizer companies add minor nutrients such as boron or manganese to certain brands to meet all probable needs, at the same time avoiding danger of over-dosage and possible toxic effect. Some add vitamin B_1 or other growth-promoting substances, but the value of these for vegetable crops has not yet been established.

Buying fertilizers. In commercial vegetable production, the fertilizer bill is a big item. At the same time, fertilizers have risen in price less than most commodities the farmer has to buy.

As with other purchases, the grower should buy from dependable dealers. Radical and costly changes in practice should be made only after study, consultation with the county agent and other growers, and, perhaps, trial on a small scale. A farmer cannot run an experiment station, but it is worth while to skip a drill width occasionally in applying fertilizer to check results. Observations of more than one year are needed.

Cooperatives have done fine work in offering reliable goods, in making open-formula mixtures available, and in reducing costs. Their competition has helped to raise and maintain the service and to lower the prices offered by privately owned fertilizer companies.

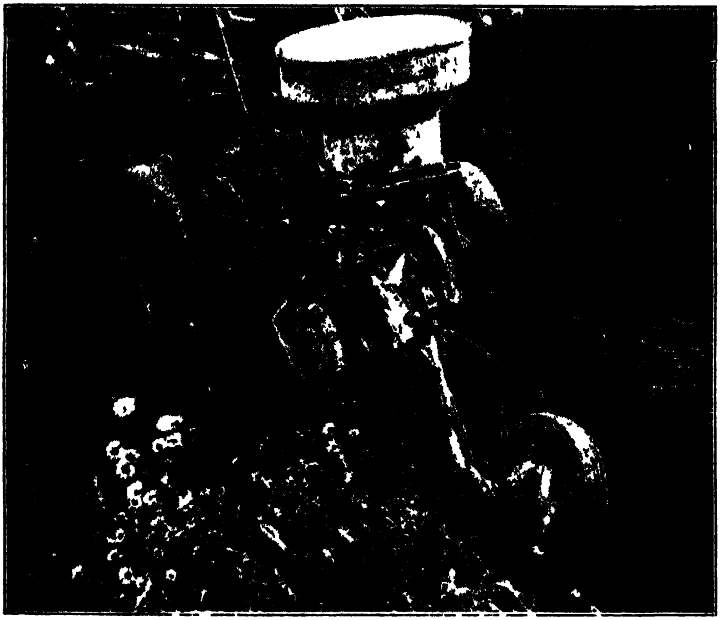
Change in fertilizer thinking. It has long been customary to decide on a fertilizer treatment in terms of, say, 1,000 pounds of 4–12–4. When the farmer considers the use of more or less fertilizer, he is likely to think of 1,500 pounds or 500 pounds of 4–12–4. He is linking his three elements in a way that may not be appropriate. If he changes one element, should he also change the others in the same proportion? Assuming that more nitrogen is needed, does it follow that a similar increase in potash would be equally useful?

A better line of reasoning would be as follows: "Experiments and experience show that, for tomatoes in our county, 60 pounds of nitrogen is about right. I'll use 120 pounds of phosphorus because it favors earliness which I want. An excess will not be wasted. Our soil is low in potash, so I'll figure on 150 pounds of potash." Now comes the time to find an analysis to fit. The ratio is 1–2–2½. That is not a standard ratio. In fact, it would be pretty hard to be sure that 1–2–2½ is better than 1–2–2 or 1–2–3. So, he takes a 1–2–2. He can buy an 8–16–16, a 5–10–10, or a 4–8–8. It would take 750 pounds of the first, 1,200 pounds of the second, or 1,500 pounds of the third. Since he can get his nutrients at lower cost per unit in the double strength, he takes the 8–16–16. The potash is still a bit low, and, as the soil is sandy, a little extra nitrogen will do no harm, so he applies 900 pounds of the 8–16–16. Even so, the 900 pounds will cost about the same as 1,500 pounds of 4–8–8.

This form of reasoning *carries each element on its own merit* and is coming into more general use.

Applying fertilizer. Commercial fertilizers are commonly applied by two general methods—broadcast and placement.

Broadcasting is usually done after plowing, before final fitting, by means of a lime or fertilizer distributor. On heavy soil, fertilizer may be spread and plowed under. On sandy soil, there



N. Y. (Geneva) Expt. Sta.

FIG. 10.5 Plowing under a heavy crop-growth with excellent covering Note that fertilizer is being applied in the furrow.

would be too much leaching. Broadcasting is a good method where land is worked fairly intensively and where a long-time program of fertility maintenance and upbuilding is carried out. A distributor should carry an adequate load, should spread the material evenly, and should not be subject to clogging, assuming that the fertilizer has been properly mixed and stored. *Machines should be well cleaned after use to avoid rusting.*

Placement [21] of fertilizer is especially desirable for situations where land is poor, crop return is low, money is scarce, or wherever it is desirable to get maximum increase in yield with minimum outlay. The advantages of placement have been well

demonstrated; a given amount of fertilizer under placement has been known to give results double those from a similar amount broadcasted. Placement consists in applying fertilizer by means of a special attachment on the planter, which places the material in a band on each side of the row, near enough to seed to give immediate results in early growth of the plant but not so near as to injure the seedling. This is usually 2 or 3 inches away on either side and a trifle deeper in the soil than the seed. Beans and peas are especially sensitive to fertilizer injury. The same sort of equipment is used on transplanters. See the chapter on potatoes for suggestions for placement without costly equipment.

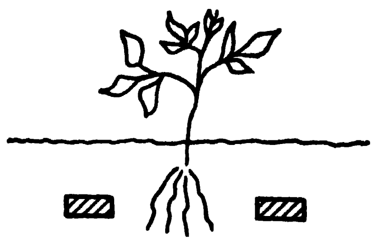


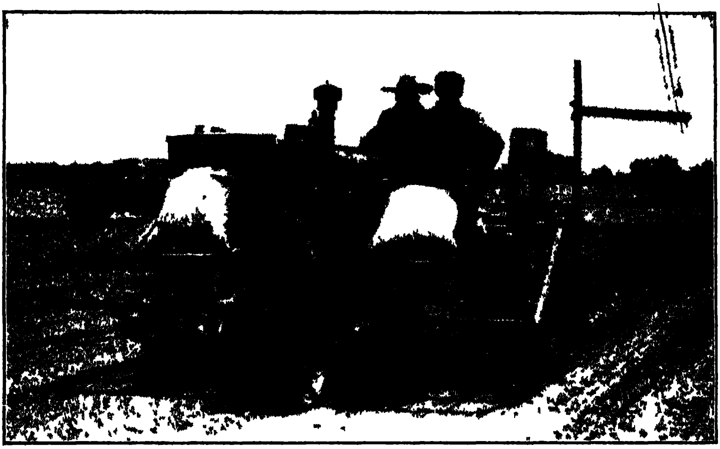
FIG. 106 Fertilizer placement. Fertilizer is distributed in two bands, on either side of roots of transplants or of seeds.

The value of placement is at least partially explained in several ways. (1) Fertilizer is not so greatly diluted in the soil. (2) The fixation capacity of the soil is satisfied in the narrow band, and fertilizer is not tied up to satisfy that capacity throughout the soil. (3) Nutrients well placed are available to the narrow root system of the young plant and so favor vigorous early growth, which is an important factor affecting total yield.

Starter solution is most commonly made by dissolving a high-analysis, readily soluble fertilizer in water. It helps give a quick start to transplanted plants by supplying nutrients when and where they are needed and by establishing close contact between root and soil. It is used in the transplanting machine or may be poured in the hole after the plant is placed and before soil is filled in. Among available analyses are 15–34–14, 23–21–17, or 20–20–20, dissolving 4 pounds in 50 gallons of water and applying about ½ pint per plant. If such material is not available, use 12 pounds per 50 gallons of a 5–10–5 or 5–10–10 or 8 pounds of a 8–16–8. These latter, however, will not dissolve completely.

Side dressing is the supplemental application of fertilizer after plants have established themselves in the soil. Since phosphorus and potash are not readily leached from most soils, it is

usually more economical to apply these as a complete fertilizer before or at planting. Nitrogen applications, especially in light or poor soils, have proved notably effective. Ammonium nitrate is now commonly used and is relatively cheap. The nitrate part of its nitrogen is immediately available but the ammonium part is more slowly available. Sodium nitrate is excellent but a little more costly. Some use is now being made of liquid am-



King Farms

FIG. 107. Planting beans, four rows at a time, with equipment for band placement of fertilizer

monia applied several inches underground, with special equipment. Since this must undergo nitrification, it should not be used until the soil is warm. Rates of application commonly range from 20 to 40 pounds per acre of actual nitrogen.

ANIMAL MANURES

Stable manure is far less important in intensive commercial gardening than it formerly was, but where it is to be had, growers of market crops value it and let none go to waste. Gardeners in the Eden district near Buffalo put crop residues in the silo and keep beef animals in the winter. In various regions animal and vegetable farming are combined. For the farm garden, manure is unmatched for convenience in use and for abundance of return.

Properties. Animal manures are widely variable in content of dry matter and nutrients. On a dry basis, they carry one-fourth to one-third their weight in *organic matter.* That is, a mere 6 tons of stable manure will supply as much organic matter as a heavy growth of cover crop. Horse and cattle manure carries roughly 0.6% of *nitrogen,* 0.3% of *phosphoric acid,* and 0.6% of potash. Ten tons, therefore, is roughly equivalent to 1 ton of a 6–3–6 fertilizer plus a heavy addition of organic matter. Phosphorus content is low, but phosphorus is also the cheapest fertilizer material. Ten tons of poultry manure would be equivalent to about 1 ton of a 10–8–5 fertilizer. A thousand pounds of 18 or 20% superphosphate will build the 10 tons of manure up to the equivalent of a ton per acre of a 6–12–6, and that is a liberal treatment for commercial garden crops. The phosphorus is broadcast upon the land or, even better, it is used in the stable where it helps prevent losses from the manure. Animal manure also contains many of the *minor elements,* and it is an excellent carrier of *beneficial soil organisms* beside furnishing nourishment for their growth and activity.

Manure needs to be well cared for. One of the best ways in most climates to conserve the full value of manure is to get it onto the ground at once, plowing it under as soon as possible. For many home gardens in the north, the best plan is to plow manure under in the fall, unless the soil is heavy. The pile in which manure accumulates should be compact and moist. Otherwise, it heats in fermentation and even firefangs—a term which describes the effect of a destructive fungus that leaves a light fluffy white residue. At the same time, the heap should be protected from leaching and drainage

Well-rotted manure is suitable for a garden that is to be planted at once. The proportion of organic matter and nutrients has not greatly changed, but there is likely to be only half the original amount.

Rate of application. In greenhouses where crops grow all the year and the depletion of organic matter is continuous, 40 to 50 tons per acre is considered ample; 20 tons per acre is generally adequate for rather intensive cropping in the open, especially if it is supplemented with phosphorus. For crops like sweet corn, cabbage, and tomato, 10 or 12 tons of manure will give marked results; it should be applied to a previous crop or at least the

previous fall, depending somewhat upon the climate and nature of the soil. For most home gardens 20 tons per acre with 800 pounds per acre of 20% superphosphate is good.

Composting. Manure from feeding yards is heavily used in the Salinas, California, truck-crop area. It is customary to compost this manure before applying it to the soil. This means serious loss but is claimed to break down coarse material, increase the availability of nutrients, and destroy weed seeds. Experiments have shown marked increase in lettuce crops from manuring. See page 483.

BUILDING A FERTILITY SYSTEM

No book can tell how to make a soil-maintaining and soil-building program for a given farm. Study of principles and research results, consideration of the crops and soils involved and of the custom of the neighborhood, local advice and personal experience—all of these must contribute to the answer.

It has been shown in comprehensive experiments in Rhode Island, Ohio, Pennsylvania, and elsewhere,[9] that commercial fertilizers and green-manure crops can be effectively substituted for stable manure.

Where soils are light and poor, conditions may demand a hand-to-mouth system, including placement applications of commercial fertilizers and one or more side dressings as crops progress.

For processing and the less intensive market crops in humid climates, a long-time soil-maintenance program may be adopted with a rotation including sod or alfalfa. As such vegetable crops are often grown on general or dairy farms, the available stable manure is applied to the land with phosphorus as a supplement. Thus an economical system of crop production and soil maintenance is achieved. On other farms a complete fertilizer with high phosphorus, a 4–16–4 or 5–20–5, may be used. On the sandier soils a 1–2–1 or a 1–1–1 ratio may be satisfactory. The muck soils usually receive heavier applications of potash. In irrigated regions several years of alfalfa may alternate with a few years of vegetable cropping.

Watts (see ref. 6 of Chapter 1) emphasizes the necessity for a suitable balance among the items that make up a fertility-

maintenance program. Behavior of a crop may suggest that too much nitrogen has been used and there may instead be a shortage of phosphorus or potash.

The wise farmer watches his soil and his plants very closely. He finds satisfaction as soil becomes darker, more fibrous and flocculent, less inclined to crust, and, best of all, more productive. He watches the color of his plants, the stockiness or slenderness of their stems, the appearance of spots or blotches or lesions of any sort. Then, he needs to know his science to help him interpret into action the things that he sees. He will need all the reading and advice that are available. Even then, he will often be puzzled.

THE LIMITING FACTOR

Throughout the study of fertility, and in fact in all relations, it is well to remember always the doctrine of the limiting factor.

Statement of principle. It is a matter of common observation that no amount of fertilizer added to a soil will give a good crop if too little moisture is present. Here, moisture may be called the *limiting factor.**

Plant growth is dependent on many factors, including light, temperature, moisture, and nutrients.

Performance in a given instance is not determined by the average of *all* factors or by the factor that is present in *most* favorable degree; rather it is governed by the factor that is present in *least* favorable degree. Thus, it is governed by the factor that is *in minimo,* that is, by the *limiting factor.*

Illustration. If available nutrients in the soil are abundant and water is supplied in varying amounts to various parts of a dry field, the increase of growth under treatment will be roughly proportional to the *amounts of water* that are added.

Suppose that nitrogen and phosphorus are present in abundance and that potash is the limiting factor. Then suppose that one adds a complete fertilizer in various amounts to several plots. The response of the plants will be roughly in proportion to the additions of *potash* and not in proportion to the additions of either of the other elements or of the *total* fertilizer added.

* The principle was advanced by J. F. von Liebig, a German chemist, 1803-1873.

As long as one factor remains in minimo, additions of other factors are, in general, not effective.

Application of principle. The relations of various factors to the plant, and the relations of these factors one to another, are so complicated that no principle of this sort can be applied very definitely. There are interactions by which one factor influences a second factor which in turn affects performance. Even though oversimplified in statement, the principle of the limiting factor, in its basic form, is an important guide to clear thinking about the management of crops.

The farmer undertakes to discover what factor is in minimo at a given time and to correct that situation. As he looks for further improvement in his return, he will seek to correct other factors, one or more at a time, until he has reached as good performance as he can reasonably expect. After he has corrected all the conditions within his power, he will reach the point where further increases in yield will either be impossible or will cost more than would be justified by the returns from the crops.

The more factors the farmer undertakes to control, the more exacting is the quest, and, also, the greater the hazard from error in the management of any one or more of these factors.

A specific illustration. Consider the supply of nitrogen (N), phosphorus (P), and potash (K), for a crop, assuming that all other factors are available.

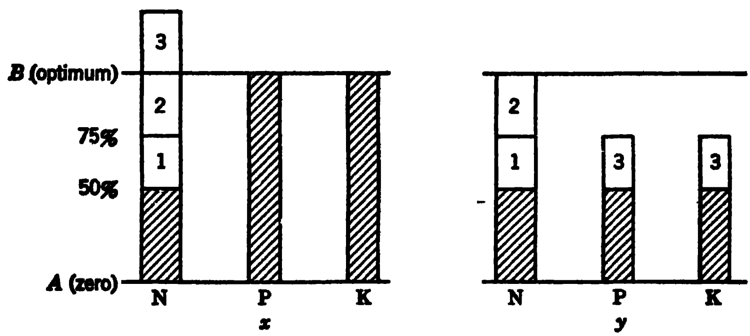


Fig. 10.8. Illustrating limiting factor. See text.

Let line A, Fig. 10.8, represent *no* supply of a nutrient. Let B represent the optimum (best) quantity—the quantity beyond which there is no betterment of the crop.

Assume that P and K are present in optimum quantity; N, at 50% level (Fig. 10.8, *x*). The growth of plants will correspond roughly to the N level, not to the P and K levels. Additions of P or K or both will have little effect.

Let N be brought to the 75% level (1), and response will rise roughly proportionately. Let N be brought to the optimum level (2), and another increase is noted, but N added beyond that point (3) will be ineffective.

Assume that N, P, and K are present in 50% optimum quantity (Fig. 10.8, *y*). We now supply N to bring the N level to 75% of optimum (1), adding no P or K. Will there be response? Not likely. We add more N (2), bringing the level to optimum. Still no response.

Now, we try again. We bring all three to the 75% level (3). Response follows, roughly proportional to the increment of all three. All three were in minimo, and an increment of any one was ineffective unless the others were increased.

If response is not satisfactory after all three nutrients have been brought to the optimum level, we naturally assume that some *other* factor must be in minimo: water, temperature, length of day, or perhaps a minor nutrient.

SOLUTION CULTURE

Growing of plants in culture solution, consisting of water and the necessary nutrients for growth, has long been an important research technique. Much publicity has been given to the possibilities of solution culture, or water culture, or hydroponics as a means of producing food in quantity. Although the method has been used to some extent for flowers and to a very limited extent for greenhouse vegetables, no great headway has been made. There are many serious obstacles to be overcome in addition to high cost. The method has been used for military food supply on barren islands, and also in Japan, where sanitation is a serious problem. For a good, unbiased discussion see ref. 17.

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11

Fitting the Land and Planting the Crop

Plow deep while sluggards sleep
And you'll have corn to sell and keep.
—*Poor Richard's Almanack, 1757.*

PLOWING

Good plowing has been a symbol of good farming for generations untold. An even furrow and perfect coverage are marks of good plowing. Plowing and harrowing are the two main operations in getting soil ready to plant. Together they are called *tillage.*

The reasons for plowing are: (1) to incorporate sod, green-manure crops, and crop residues in the soil; (2) to destroy weeds and often insects; (3) to improve the texture and aeration of the soil.

Plowing may be omitted when there is little plant material on the land. It is often omitted when more than one crop is grown in a season or when cover crops are to be sowed. Disc harrows will dispose of quite a growth of weeds or even of a not-too-heavy crop residue as of beans or peas.

Laying out for plowing should keep dead furrows and back furrows to a minimum. For this reason, reversible plows are good.

A large plow, with 12- or 14-inch bottom, does a better job of covering plant material than a smaller one. Ample power, whether animal or tractor, is required for a good job.

Relatively deep plowing is desirable. If subsoil is close to the surface, not much of it should be brought up at one time, but depth should be increased gradually down to, say, 8 inches. Depth should be varied somewhat in successive plowings, espe-

cially with heavier soils, to avoid forming a plow sole, a rather impervious, partly puddled layer just under the plow.

Actual loosening of soil is of value in promoting aeration in heavy, fine-textured soils, but, after all, roots have great capacity for penetrating soil. Moreover, fairly compact structure favors the close contact between seed and roots on the one hand and soil on the other that is necessary in order that plants may readily absorb moisture. Water films do not jump across air spaces unless the soil is actually saturated, and it does not long remain that way if plants are to grow in it. Aeration is necessary to provide oxygen for the life processes of roots and of desirable soil organisms. On the other hand, undue compaction of soil by tractor wheels and other implements has been shown to be harmful to crops. Loose structure is especially desirable for rootcrops.

Plowing under heavy growth. See page 172.

Plowing soil when it is wet is bad for its texture: puddling and lumping result, crumb structure is injured, and drainage and aeration are retarded. These dangers are more serious on heavy than on sandy soils and in spring than in fall plowing. One must learn from his own soil just when it is dry enough to plow, grasping a handful and judging by its action and appearance when pressed and crumbled.

Fall plowing. In northern climates, where the land freezes over winter, fall plowing is good practice, especially on land needed for early spring crops. In the south, the practice is less desirable on account of erosion and leaching.

One cannot say, "Always plow in the fall," or "Never plow in the fall." Five points are to be considered in deciding what is best for a given piece of land.

1. Fall plowing conserves plant material and gives it opportunity to decompose over winter, though this process is slower in cold than in warm weather. On the other hand, it cuts off late fall and early spring growth of sod or cover crop.

2. Leaving the soil in rough furrows may retard run-off of water and curb erosion. If, however, the soil does not freeze, erosion and leaching may be favored.

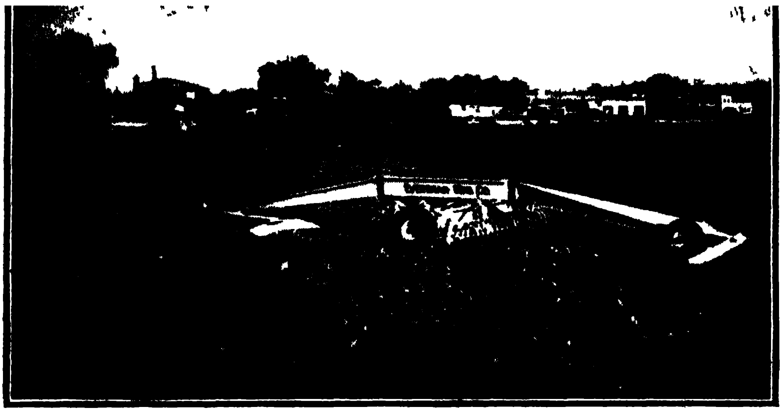
3. The action of frost tends to break up hard and puddled clods and so to improve texture.

4. When land is plowed late, insects are likely to have set up their winter homes, and fall plowing destroys many of them by exposing them to the weather.

5. Fall plowing relieves the pressure of spring work and gets the land ready for early planting.

HARROWING

Many implements, and many variations thereof, are available for the preparation of soil after plowing. A large investment



Eversman Manufacturing Company

FIG. 11.1. Land leveler to prepare for even sowing of seed and for efficient furrow irrigation. This is a small one. Large operators use huge machines of the same sort.

would be required to provide just the right device for every occasion, but a simple array of tools meets most needs in tillage, and it costs far less. Just what tools to select will vary with the soil and the cropping system. The *disc harrow* (Fig. 6.3), the *spike-tooth harrow* (Fig. 6.4), and the home-made *plank drag* (Fig. 6.6) will fill most requirements.

The *Meeker harrow* is a useful addition to the set. See Fig. 6.5. It comes the nearest of any common implement to doing a hand-raking job, and it is well-nigh indispensable for small-seeded crops like lettuce and carrots.

The *spring-tooth harrow*, Fig. 6.2, is still valued by many. It is more thoroughgoing than the spike-tooth harrow, but it tends

to drag up sods or plants rather than to push them into the soil as a disc does. It pushes clods aside instead of crushing them as a planker does.

A more expensive addition is some form of *pulverizer* or culti-packer, Fig. 6.1, of which there are several. A *roller* costs little and is valuable for clod crushing and for pressing newly plowed soil down upon a heavy green crop, so favoring its decomposition. Land levelers are finding increasing use, Fig. 11.1.

Rotary tillers are used to some extent for preparation of soil before planting and for inter-row cultivation.

Timing of harrowing operations is a delicate job. Clods break up best just after plowing. Harrowing when soil is too wet is messy; when it is postponed too long, clods are not readily broken. When timed just right, harrowing helps materially in drying out the soil and in getting it ready to plant.

PLANTING SEED

Of forty leading vegetable crops, thirty are always or nearly always planted where they are to grow to maturity. Only about ten are commonly started in seedbeds or under glass. See Table 11.2.

Two objects are to be sought in planting vegetables: proper timing and a proper stand.

Time the planting to fit the climate

How early or how late it is safe to plant a given crop is a common question. The time to plant crops is decided on the basis of (1) the local climate; (2) the hardiness or tenderness of the crop; (3) the time when the products are wanted; and (4) what land is available for use.

Home gardeners in almost all climates begin to plant certain hardy vegetables as soon as they can work the ground. In perhaps nine-tenths of the United States this begins as soon as danger of severe freezing is past in late winter or early spring. This statement should not be interpreted to mean that all danger of frost is past. In the other tenth, hardy vegetables may be started in the fall and left in the field throughout the season of freezing danger. Those parts of the United States where tender

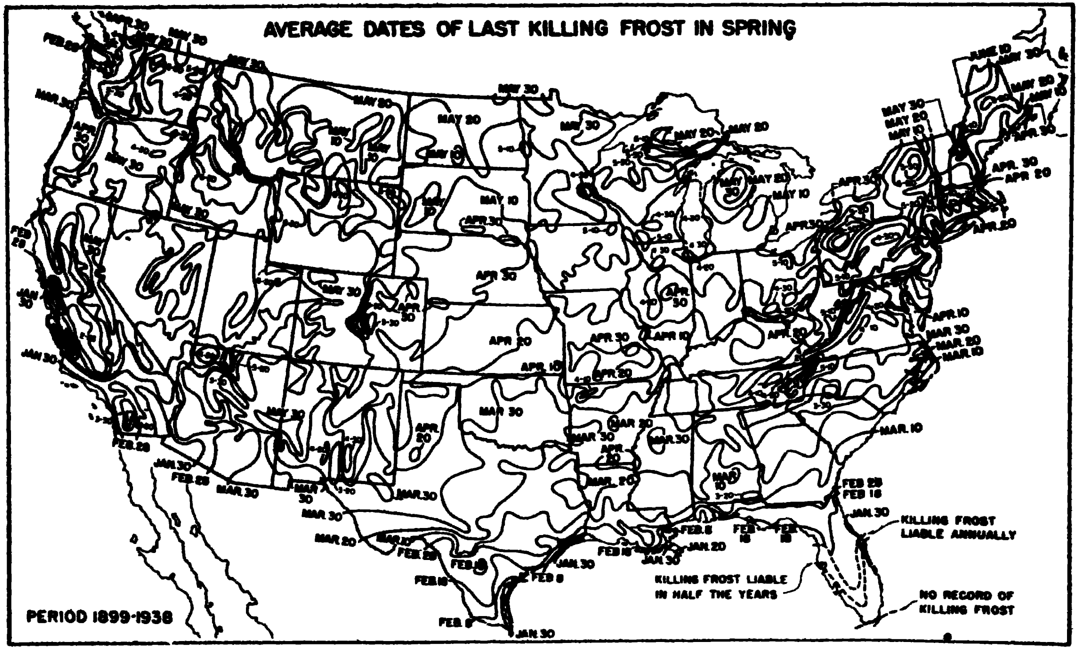
kinds of vegetables, like tomatoes and melons, thrive in midwinter are very limited in area.

In much of this country, the gardening season is limited in summer by heat and drouth. Pickett [4] gives an excellent chart on planting seasons in Texas. Watermelons and sweet potatoes are relatively hardy to both heat and drouth, but spinach, peas, lettuce, and cauliflower are sensitive to high temperature. Shipping of potatoes, cabbage, and onions from the north to the south has been big business for decades. As buying power in the south increases, opportunities of this sort become greater.

Study local climate. Both gardeners and farmers should inform themselves about the local climate, especially as regards temperature. Few people know much about it, but the Weather Bureau offices have gathered data for many decades, and this material is summarized nationally and by states in "Climates and Men." [1] Some states, as Florida and New York, have special bulletins on climate. Weather Bureau figures are not sufficient. On a given frosty morning there may be 10° F. difference within 10 miles. Elevation and bodies of water have marked influence.

Critical dates. Weather records include the average date of the *last killing frost* in the spring and the *first killing frost* in the fall. See Figs. 11.2 and 11.3. The number of days between these averages is called the *length of the growing season.* In New York state alone the range among localities is amazingly wide, from 90 to 200 days.

It must be remembered, however, that *average dates* do not represent *danger dates.* For example, at Ithaca, N. Y., average dates are May 4 and October 11—a period of about 160 days. The growing period for *hardy* kinds, like cabbage and carrot, is longer than this. But danger of late frost is such that setting of tomatoes is not safe until the last week of May, and the crop should be harvested by mid-September to avoid risk of loss by frost. That gives a real growing period for *tender* crops that is nearer to 110 days. For home and market purposes, one can afford to take greater risks with limited plantings of tomatoes. Early fruit commands good prices, perhaps 20 cents a pound or even more. There is often ready sale for late-planted tomatoes as they are likely to be of good quality when the "clean-up" pickings of old fields are poor.



U. S. Weather Bureau

FIG. 11.2. Average spring frost dates for the United States. These charts furnish the best general guide as to times of planting vegetables, but they must be used in the light of local information. Ten miles' travel may reveal ten days' difference in frost dates.

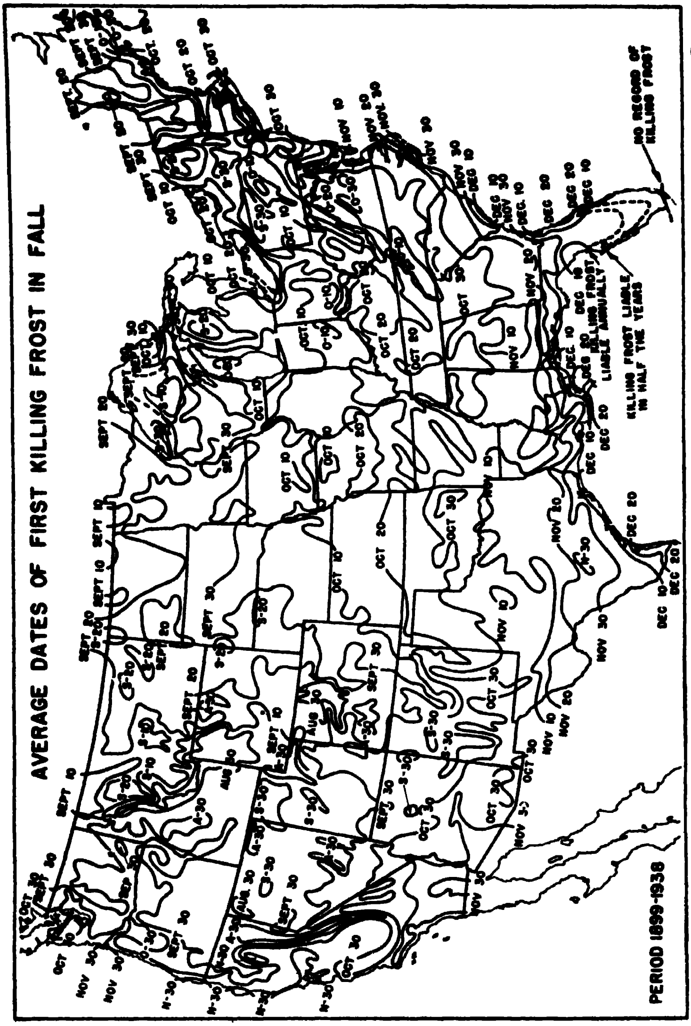


FIG. 11.3 Fall frost dates for the United States. — *U. S. Weather Bureau*

Information like that given in Table 11.1 helps in calculating the risks of frost injury. Similar data may be had for most Weather Bureau stations. The temperature where the plant actually is must fall a couple of degrees below 32° F. before freezing and injury of tissue occur.

TABLE 11.1. LATE FROSTS AT ITHACA, NEW YORK

Based on occurrence of 32° temperature, not on record of "last killing frost." Data for 60 years. Similar tables can be made from Weather Bureau data for any region.

	Date	*Times 32° Was Reached*	*Minimum for 60 Years*
May	1st week	48	22° F.
	2nd week	24	27°
	3rd week	15	29°
	4th week *	8	31°
June	1st week	2	32°

* Considered safe for setting tomatoes.

With a table of this sort, one may decide what chances he is willing to take. Thus, one might plant 80% of his tomatoes the last week of May, 15% the third week, and 5% the second week. If May is warm and sunny, the first plantings are likely to yield a fine return. If not, the loss is small.

Crop differences. Vegetable crops are arranged according to hardiness to frost in Table 11.2. Column headings suggest when to plant these groups in relation to the average date of the last killing frost for a given locality, but such suggestions must be applied in the light of local experience.

It must be remembered that crops differ in reaction to low temperatures *above* freezing as well as to frost. Tomatoes do not thrive in cloudy, cool weather. Cabbage is frost-hardy and will start into immediate growth when the weather warms up even slightly. Both cucumbers and watermelons, of the cucurbit family, are killed by slight frost, but cucumbers require only a short season and do well in relatively cool weather. Watermelons require a long season of warm sunny weather.

Some plants, such as cabbage and lettuce, recover readily from a check due to cold; tomatoes and melons, less readily.

TABLE 11.2. VEGETABLES CLASSIFIED BY HARDINESS

This classification refers to sensitivity to frost injury and is not to be confused with classifications based on length of growing season, or on temperature requirement during the growing season. Thus, of "very tender" crops, cucumber thrives with a short and relatively cool season; watermelon requires a long warm season.

Suggestions as to planting time cannot be applied rigidly. Local conditions must be considered.

Hardy	*Half Hardy*	*Tender*	*Very Tender*
Plant as soon as ground can be prepared	Plant 1–2 weeks after average date of last killing frost	Plant 2–3 weeks after average date of last killing frost	Plant 3–4 weeks after average date of last killing frost
Asparagus	Cauliflower	New Zealand spinach	Cucumber *
Beet *	Celery †	Snap bean	Eggplant †
Broccoli	Potato	Sweet corn	Lima bean
Cabbage †		Tomato †	Muskmelon *
Carrot			Okra
Kale			Pepper †
Lettuce *			Pumpkin *
Onion *			Squash *
Parsnip			Sweet potato †
Pea			Watermelon *
Radish			
Rutabaga			
Salsify			
Spinach			
Swiss chard			
Turnip			

* Plants are sometimes set instead of sowing seed. If seed is used, planting may be a week earlier.

† Plants are usually set instead of sowing seed.

The weather at the time of the proposed planting must be taken into account. If the usual plant-setting time is marked by cold soil, and damp, cool, cloudy weather, tender plants are better off in the frames than in the field.

It is desirable to learn the elementary facts about weather, the movement of fronts and storms.[5,6] Follow the local forecasts. Some radio stations now offer comprehensive reports from a number of scattered stations, followed by a general summary of conditions and forecasts from a U. S. Weather Bureau office.

Personal observation and note-keeping. As with so many of our dealings with the forces of nature, rules help little, and general statements must be very general indeed in a land of such widely varied climate. Each person must know the habits and requirements of his plants and the vagaries and dependabilities of his own climate. Careful observation of soil and of wild plants and judicious listening to the weather lore and experience of other gardeners all help. A careful though simple record of planting dates, maturity dates, and general weather conditions becomes very valuable when it has been kept for even as little as three or five years.

Succession plantings. In planting for a market succession of a given crop such as sweet corn, progress of the earlier plantings must be taken into account as well as dates. Time from sowing to silking of sweet corn may vary by as much as 30 days for the same variety. Therefore it is well to make a second sowing when the first comes up, and so through the season. Also, late plantings will need more time than mid-season maturities. If this principle is not observed, one may have three sowings coming on at once.

Degree days. Many years ago attempts were made to relate growth of plants to summations of temperature from an assigned base. Thus, with 40° as a base, days with mean temperatures of 52, 63, 48 would give a sum of 43, often called degree days or heat units, the latter not to be confused with true heat units such as B.t.u. or calorie. The method is used for timing plantings to provide uniform supply for processing and to estimate the probable date of maturity of plantings already made. The method has proved useful with peas, sweet corn, and snap beans, but other factors such as moisture supply, sunshine, and others may complicate the picture. It is not as simple as it looks.

Other timing factors. In planning dates and areas to be planted, regard should be paid to times of best market demand and prices, to the distribution of costs through the season as well as the distribution of income and labor to meet those costs, and to the fullest utilization of land and its maintenance in high fertility.

GETTING A GOOD STAND OF PLANTS

The aim in planting seed or setting plants is to achieve a *good stand,* to have plants at the best possible *spacing* for a large crop of fine quality. No amount of fertilizer or water or care will bring a good crop from plants that are not there.

TABLE 11.3. PLANTING RATES AND QUANTITIES

Rates of sowing seed in the home garden and distances between plants after thinning. Rates per acre vary too widely to be included in a table. See crop chapters.

Vegetable	*Number of Seeds per Foot*	*Distance between Plants after Thinning, inches*	*Number of Seeds per Ounce*	*Quantity Needed for 100-Foot Row*	*Quantity to Order for 100-Foot Row*
Bean, lima	4–6	4–6	20–90	1/4–1 lb.	1/2–1 lb.
Bean, snap	6–8	2–4	65–90	1/2–3/4 lb.	1/2–1 lb.
Beet	10–15	2–3	1,400	3/4–1 oz.	1 oz.
Carrot	15–20	1–3	26,000	1/20–1/15 oz.	1 pkt.*
Chinese cabbage	4–6	12	18,000	1/40–1/30 oz.	1 pkt.
Cucumber	1–2	24–48	1,200	1/10–1/5 oz.	1 pkt.
Endive	4–6	12	17,000	1/40–1/30 oz.	1 pkt.
Kale	4–6	12	9,000	1/20–1/15 oz.	1 pkt.
Kohlrabi	6–8	4–6	8,000	1/12–1/10 oz.	1 pkt.
Lettuce, head	8–10	12	23,000	1/30–1/20 oz.	1 pkt.
Lettuce, leaf	10–15	6	23,000	1/20–1/15 oz.	1 pkt.
Muskmelon	1–2	24–48	800	1/8–1/4 oz.	1 pkt.
Onion	10–20	Not thinned	10,000	1/8–1/5 oz.	1 pkt.
Parsnip	15–20	3–4	6,000	1/6–1/4 oz.	1 oz.
Pea	10–15	1–2	90	3/4–1 lb.	1 lb.
Radish	10–15	1–2	3,400	1/4–1/2 oz.	1/2 oz.
Rutabaga	10–15	6–10	11,000	1/10–1/7 oz.	1 pkt.
Spinach	15–20	2–4	3,000	1/2–1 oz.	1/2–1 oz.
Squash, pumpkin	†				1/2–1 oz.
Sweet corn	1–2	9–12	110–220	1/2–2 oz.	1/2–2 oz.
Swiss chard	8–10	6	1,200	3/4–1 oz.	1 oz.
Turnip	10–15	4–8	10,000	1/13–1/10 oz.	1 pkt.
Watermelon	†	48–96	150	1/2–1 oz.	1 oz.

* Quantities in packets vary widely.
† Hills or single plants, spacings and quantities vary widely.

If plants are too thickly placed, they crowd each other and, like weeds, reduce both quality and yield. If seeds or plants do not find close and even contact with soil particles, they absorb moisture unevenly; some grow rapidly and some grow

slowly or fail. An irregular and unprofitable stand is the result. If one learns how to get a good stand in the home garden by hand, he will know how to judge machines and methods for commercial plantings.

Hill versus drill. In times past, all but the small seeds were planted in hills. Thus five or six seeds of sweet corn would be dropped every 3 or 4 feet in rows with the same spacing between rows. The same plan was followed with cucumber, squash, melons, and even beans. The modern trend has been toward sowing in drills, that is, with close spacing in the rows. It is considered that three sweet corn plants will do better a foot apart in the row than if bunched in a hill. On the other hand, if land is weedy, the opportunity for cross cultivation may favor the hill system.

Rows are often grouped, two to six in a bed, which may be raised for furrow irrigation and for drainage or they may be level. This allows space for wheel tracks of cultivators, dusters, and sprayers and is a convenience at harvest time. Good bed-forming equipment is available. All planting and cultivating equipment must then be set for the same number of rows per bed.

Garden planting of seed includes three jobs: (1) making a furrow; (2) sowing the seed; (3) covering the row.

We assume that the soil has been well prepared: spaded and raked or plowed and harrowed. Finer raking or harrowing is needed for smaller seeds than for larger, but in any event, the soil surface should be even and free of large lumps.

For spacing and depth of planting, see Table 11.3 and also the chapters on specific crops.

Depth. In general, small seeds are planted shallow—carrots and lettuce at, say, ¼ inch. Large seeds are planted deeper—peas and beans at about 1½ inches. Plant shallower in heavy soils and when rain is likely; deeper in sandy soils and in drier seasons.

Dry-weather planting. For a good come-up in dry soil, the furrow may be made deeper than usual. Then seed is sowed and covered with only a half inch of soil, the soil being pressed firmly for good contact. In the home garden, moistening the seed and a bit of surrounding soil with a small amount of water will assure germination; of course the seed must not be washed out

of place. In the field judicious irrigation is invaluable for this purpose.

Where wet weather is common at planting time, raised ridges or beds may be made.

Straight rows are worth having in the garden, home or commercial, for plants are then more easily cultivated and cared for. The sweeping curves of contour farming do not violate this principle. All good gardeners take pride in their work, and a garden of well-laid-out rows presents a pleasing appearance. The first step is to lay a taut line between stakes at either end of the row to guide in making a straight furrow. It may be placed an inch or two to one side for convenience in opening the furrow, especially when larger seeds or potato seed pieces are to be planted.

Markers. If hand planting is to be done on a large scale, the first row may be laid out by line and successive rows by marker. See Fig. 11.4. The bar of the marker may have holes so that pegs

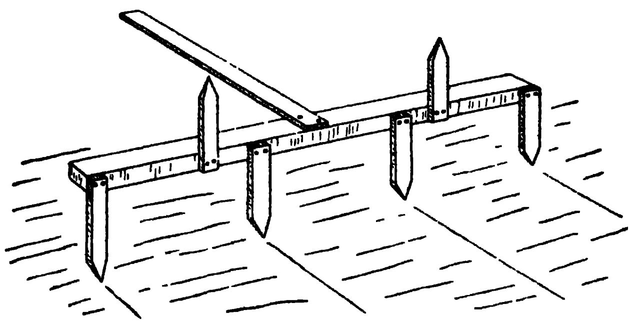
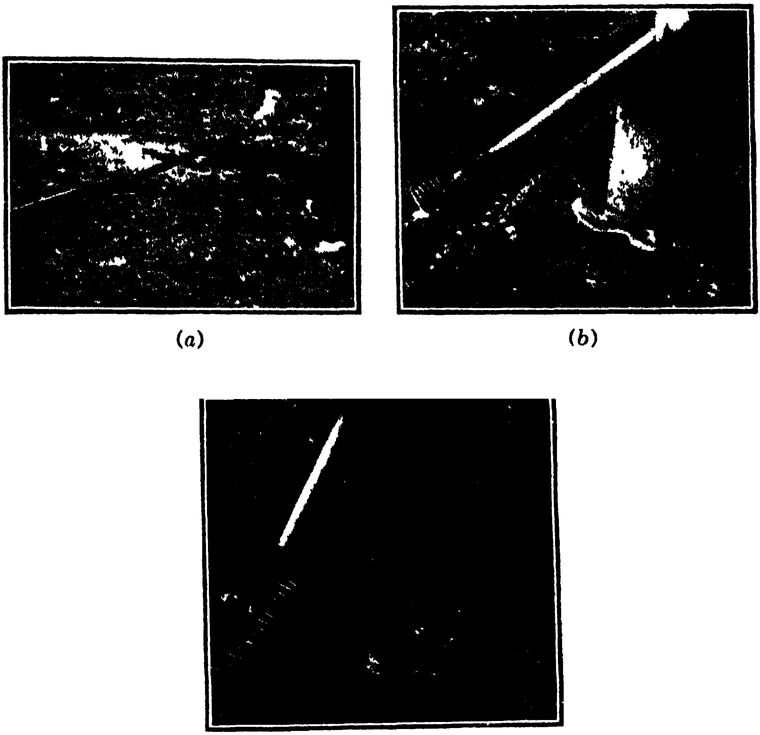


Fig. 11.4 Marker for laying out rows Some markers are made so that pegs can be adjusted.

may be set for various spacings. The same implement may be used for cross markings for hill plantings.

Making the furrow. The planting furrow should be of even depth and should preferably have a narrow, smooth bottom. The kind of furrow that would be made by pressing the corner of a board into the soil illustrates the idea, though this method is not practical outside of greenhouses, flats, and seedbeds. If seed is in a narrow band and at uniform depth, the come-up is more even; thinning, if required, can all be done at once; wheel-hoeing can be closer, and weeds are more easily controlled.

In the home garden one of the easiest ways to make a furrow of the sort just described is to use a level-back rake as distinct from a bow-back rake. See Fig. 11.5. With teeth turned up, the



(a) (b)

(c)

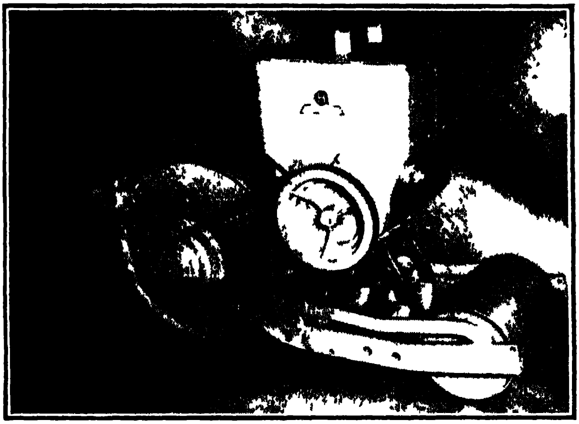
Cornell University

FIG. 11.5 Level-back rake is good for (*a*) opening rows, (*b*) covering seed, (*c*) firming the soil.

back is pressed into the soil along the row, making a wedge-shaped furrow of even depth and fairly smooth surface. For coarser seeds, the little plow that comes with some wheel-hoe sets is useful. Or the hoe may be drawn along the line to make a furrow an inch or two deep.

Sowing the seed. Table 11.3 suggests about how thickly plants may well stand in the row. How thickly to sow the seed is another story. If seed is of high germination, if conditions of soil and moisture are favorable, and if work is carefully done,

a high percentage of seeds of corn, beans, and radish will yield plants. Liberal sowing is required with kinds that germinate weakly, in heavy or ill-prepared soil, in time of drouth, or when there is danger of damage by insects such as seed-corn maggot or flea beetles. Sowing too thickly necessitates a laborious job of thinning, one of the tedious tasks of the garden which should be kept to a minimum. One should know fairly definitely the germination percentage of the seed, and then experience will teach how thickly to sow in one's own soil, under various seasons



Hallett Manufacturing Company

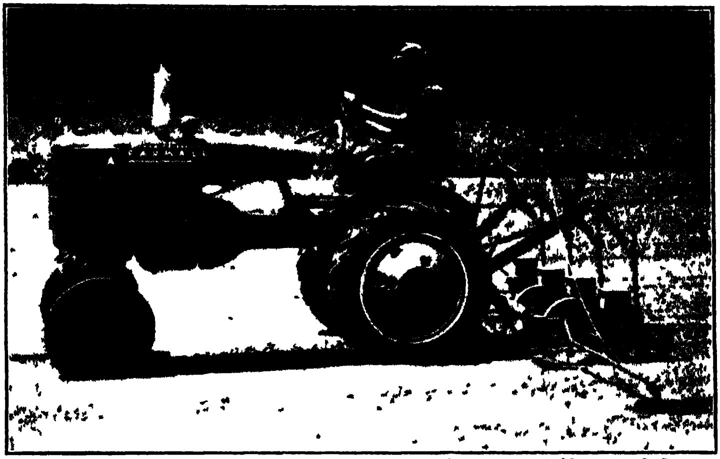
FIG. 116 Precision planters are designed to drop one seed at one spot, to gain a good stand without thinning

and conditions. Gardeners, both home and commercial, need more generally to observe their sowing rates in terms of *seeds per foot of row.* Commercial growers now use precision planters, dropping a single seed at a place. See page 125 for coated seed.

Covering the seed. Seed may be covered with the hands or fingers, with the back of the rake, or with the hoe or the little plow. Judgment must be used about pressure. Peter Henderson, market gardener, seedsman, and author, wrote a paper entitled "The Use of the Feet in Gardening." He referred to pressing the soil over newly planted seeds. He had in mind establishing close contact between soil and seed so that moisture would be absorbed and growth would be started. On a larger scale, he recommended the use of a roller. When soil is sandy and a bit on the dry side, this is still good practice. If

soil is clayey or wet, light pressure with the back of the rake is sufficient.

Seed drills. In the home garden, mechanical seed drills are seldom used unless the area is rather large It is almost as much of a job to adjust the machine and then clean it out as to plant by hand. In commercial plantings, highly developed machines of many makes are widely used They begin with single-row walking drills, which are often combined in gangs on tractors



International-McCormick-Deering

FIG 117 Drills mounted on tractor

or on huge 12-row frames For cannery peas and some other seeds, grain drills are used, closing off as many of the tubes as may be necessary for proper spacing between rows Sweet corn on a large scale is sowed with special corn planters, which are also suitable for beans and peas. Fertilizer-placement attachments are available (pages 184, 186, and 230).

Size of seed. With sweet corn, especially for cannery, it is worth while to sort seed for size. This practice may also be useful for radish, beet, and bean. Good commercial seed does not contain many badly dwarfed kernels, nor is it necessary to throw away any but very small seeds. Separation into two or three sizes makes it possible to adjust planters more accurately. If one seed is to be dropped at a place, there will be fewer pairs and fewer skips. This practice also makes for more even ma-

turity. Instead of picking over an entire plot three times, one may plant two sizes of seed separately and harvest the blocks with two pickings each, thus saving materially in labor.

Irrigation at planting time. Water may be applied before and after planting. If the soil is very dry, pre-irrigation is definitely desirable, the time being gauged so that the soil will be "about right" when it is desired to plant. This pre-irrigation should be rather thorough. Then water may be applied again after planting if needed.

With furrow irrigation, some care is required in placing rows on the top or the side of the bed for even access of water and to insure against washing out or settling away of soil and seed together.

In some soils, watering by sprinkling after sowing may result in crusting serious enough to interfere with germination. Rains may do the same thing. Especially with small seeds, it may be desirable to break the crust with a rake. This may seem dangerous, but plants are not as seriously harmed as might be expected if the work is carefully done A weeder may be used with potatoes and sweet corn.

THINNING

Some kinds of crops such as onions, peas, and beans are not injured if somewhat crowded. Many may be sowed accurately enough to give a stand within reasonable range of the optimum.

Thinning of beets, carrots, lettuce, parsnips, and the vine crops was formerly common in commercial practice, but the high cost of labor has forced measures to eliminate this tedious task. Chemical control of weeds has reduced or banished the task of hand weeding. Growers, therefore, often plant a trifle thinly and as precisely as possible and then accept a stand somewhat less than the best. Thinning still has an important place in the home garden. Sowing slightly more thickly than necessary is usually desirable with vine crops to insure a good stand. Thinning also offers an opportunity to weed out weak plants, leaving the vigorous ones.

Even if thinning is to be done, sowing should be made with care to avoid too thick a stand, which greatly increases the labor.

Thinning should be done as soon as plants are large enough

to make it convenient; if it is postponed too long, pulling plants disturbs those that remain

TRANSPLANTING TO THE FIELD

Marking out for hand setting of transplants is handled as for seed sowing. Cross marking insures proper spacing in the rows but is not essential if cross cultivation is not to be practiced. With small plants like celery, a wheelbarrow wheel with cross bars on the rim serves well to space the plants.

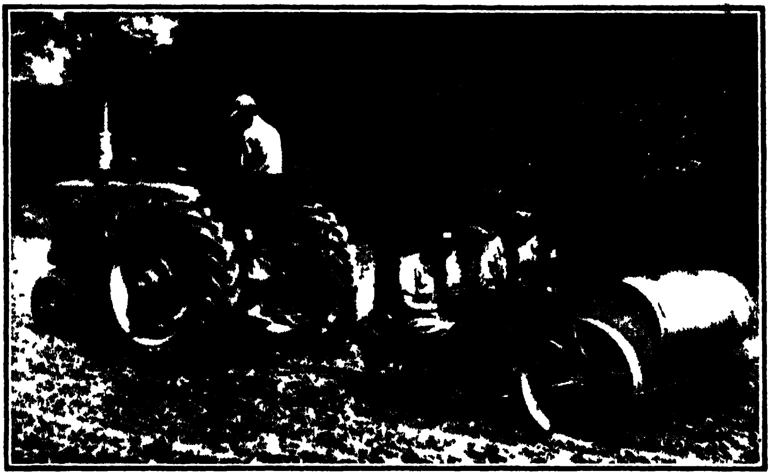
Handling plants. Beds or flats should be watered well, preferably the day before field setting of plants If in flats or pots or bands, they are hauled to the field and distributed. When plants have been set in a cold frame without containers, they may be lifted in sods with a flat, many-tined fork and hauled on a flat-bedded truck or wagon. Plants in drills in a seedbed are carefully loosened to reduce root breakage to a minimum They should not be pulled long before setting; if held, they should be protected from drying of roots and from wilting.

FIG. 118 Transplanting by hand Pour water in the hole *after* the plant is placed but *before* covering. Press soil firmly about the roots

Hand setting. For hand setting, the marks one way should be fairly deep and the cross marks rather shallow One worker drops plants for one o two setters. The setter is equipped with dibble, trowel, or short handled hoe. The hoe is good for setting potted plants. A hol is made, the plant is placed, water or starter solution is adde (see page 185), and soil is packed firmly about the root or so: block

Under another method, the setter inserts a spade into the ground to make a wedge-shaped opening; the dropper holds a plant in place; the setter withdraws the spade and firms the soil with his foot. This method is rapid and efficient.

Watering. Plants well grown and hardened, and carefully handled and set, will start off nicely unless the soil is unusually dry or the weather is very hot. Under less favorable conditions,



Baltimore & Ohio Railroad

FIG 119 Two-row transplanter (modified Holland) as used for cauliflower in western Maryland.

a bit of water, say a quarter or half cupful, may be applied after the plant is placed but before the hole is closed. Its function is to puddle the soil about the root and to establish thorough contact with the earth rather than to irrigate. If this is not sufficient, then general irrigation is needed. See page 185 for a discussion of starter solutions.

Machine setting. In large-scale operations with cabbage, cauliflower, tomatoes, peppers, and a few other crops, riding transplanters are widely used. The frame, mounted on wheels, carries a shoe which opens a furrow, seats for two planters, a water tank, a device for releasing water at the root of each plant, a pair of rollers or shoes to press the soil about the roots, and a marker for the next row. Some are mounted directly on the tractor. For celery planting, special machines have been de-

vised to insure accurate spacing and proper depth They are also suitable for cabbage and other plants Transplanters require a retinue of operators a driver for the team or tractor, two setters, and a man and conveyance to pull and haul plants and keep up a water supply A good hand-setting crew can often do the job as cheaply and well but most people are not

New Idea

FIG 11 10 Celery growers and others use setters that carry the plant to its place and release it automatically This is a two-row machine

fond of stoop labor With careful work, tomato plants with a ball of earth may be set by machine

In transplanting, roots are mutilated and so the plant is partially crippled for absorbing water to replace transpiration Hence transplanting on a cloudy day, or in the evening or in partial shade, may be useful The commercial grower cannot ordinarily take these measures, and so he must have good plants and use water as needed

Depth of setting. Most plants may be set at any convenient depth, usually a little deeper than where they grew This rule will not do for celery, lettuce, and strawberries, however, which have a very short stem or crown If they are set too deep, the growing point will be buried and smothered, if too shallow, roots will be exposed

Do not prune the plant. People often ask about pruning plants on transplanting. In the first place, plants should be grown in such a way that one is not tempted to thin away the leaves. Sometimes, weather conditions make oversized and underhardened plants unavoidable. Even then, pruning has been shown by experiments to serve no useful purpose. (See reference 10 of Chapter 9.) Even though leaves function imperfectly, they are still making carbohydrate for growth. Even though some of the leaf tissue dies, it does no particular harm if it remains. Pruning of roots is even less desirable since they have almost always suffered mutilation already.

LABELING

All plantings should be carefully labeled at the time, whether the garden is for home or market. Then records should be made

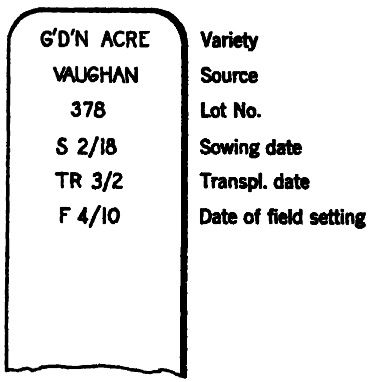


Fig. 11.11. Good and full labeling is essential. This pattern is comprehensive. Some prefer to carry part of the data in a book.

in a notebook or on a map. Data should include kind, variety, source of seed, year bought, lot, and date of planting. Labels should be large enough to be seen readily, to carry clearly visible lettering, and to resist the hard knocks that might break or remove them.

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12

Irrigation and Other Cultural Practices

One of the major developments in vegetable production has been increasing use of water for irrigation.

Since expenditure may be substantial and since technical knowledge of several sorts is required for good planning, it is important to make use of dependable consulting services. These may be available through the better irrigation companies, through extension services, or through private irrigation engineers. Books, bulletins, and commercial literature are abundant and mostly reliable.

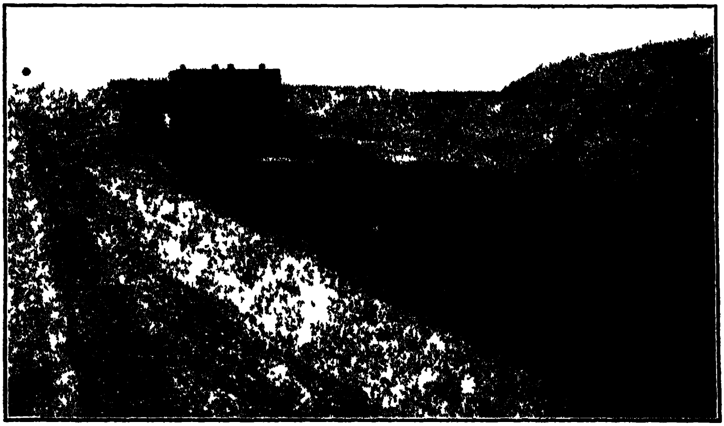
An adequate water supply is essential not only for profitable yields of vegetable crops but also for marketable quality. Nature supplies plants with water by means of rainfall, but rainfall is often inadequate. Water penetrates into the soil, distributing itself under gravity and, in small degree, by capillary movement. Excess water runs off or sinks to the subsoil and on to streams, either surface or underground. Both retention and reception of water depend on the slope of the land and the nature and cover of the soil. Sandy soils take up moisture more readily but are less retentive than heavier or finer soils.

In humid regions, rainfall ranges from 25 or 30 inches a year up to 50 or 60 inches. Reasonably distributed, this is sufficient for the successful production of most vegetable crops. But experience and records both testify that the drouth hazard is serious. Seldom, even in humid regions, does a growing season pass without at least one period of water deficit.

Weather records for seven midwestern states show an average of five to eight rainless periods of one to two weeks' duration between April and October each year, and also, in each year, one to two rainless periods of two or three weeks' duration. Of

course, there are times when there may be a little rain but still not enough to break a drouth condition. On the other hand, a rainless period of one or two weeks may begin with a full supply of moisture in the soil and do little harm. Presumably these considerations would about balance.

In arid and semi-arid regions, normal rainfall is inadequate for most crops. In some sections as little as 6 to 10 inches of rain falls annually. In others, the range is from 10 to 25 inches.



B. A. Harrigan, Agricultural Commissioner, El Centro, Cal.

FIG. 121. All American Canal carrying water from Colorado River to Imperial Valley, California.

In many of these the rain falls principally in seasons of the year when, for other reasons, crops cannot be grown.

Accordingly, much of the vegetable land of the country is dependent upon irrigation, and in most of the rest of the vegetable areas irrigation is needed to supplement rainfall. Losses from lack of water are more serious in so-called humid regions than in areas where the practice of irrigation is general.

In considering irrigation for commercial vegetable production, four general problems must be faced.

1. Appraise the need.
2. Be assured of adequate water supply.
3. Decide on type of distributing system.
4. Decide on times and quantities of application.

APPRAISING NEED FOR IRRIGATION

In deciding whether or not irrigation should be undertaken on a vegetable farm, consider (1) the crops to be grown, (2) the nature of the soil, (3) possible improvements in moisture-conservation measures, (4) cost of watering, and (5) probable gain in gross return.

1. **Nature of crops.** Some crops suffer more severely under drouth than others. Watermelons and sweet potatoes are rather drouth resistant, though that does not mean that they will do well without water. Tomatoes, potatoes, cabbage, onions, beans, sweet corn, and the vine crops may be classed as intermediate. Lettuce, celery, spinach, cauliflower, and most of the root crops are drouth sensitive.

Hardiness under drouth may be traceable to one or more of three major factors. It may be inherent in the plant itself (sweet potato), or it may be due to a widely spread root system (tomato) or to ability to grow and make a crop in spite of a drouth period, utilizing water whenever it comes (late cabbage).

2. **Nature of soil.** Sandy soils with low water-retaining capacity are more "drouthy" than heavier soils which have fine particles, great internal surface, and therefore great capacity for holding moisture. Organic matter in soils also increases retentiveness. These advantages may be partly balanced by greater resistance of the heavier soils and of the organic matter to extraction of water by the plant roots; that is, availability of water to plants may be decreased.

3. **Conservation measures.** Tillage and crop management may be planned to prevent run-off, as by the use of terraces and contour farming. The land, especially if sloping, should be covered by crops as much of the time as possible. Increasing the organic-matter content of the soil is generally helpful.

4. **Cost.** The different forms of irrigation equipment vary so widely in cost of installing, maintaining, and operating that general statements are not possible. Under a given system in a given situation, costs per acre may be figured fairly closely. These must include interest and depreciation on equipment, repairs and upkeep, water and pumping, leveling and ditching of land, and labor in applying water.

5. **Probable gain.** Among the specific advantages that may accrue from irrigation are the following:

(*a*) Maximum growth and yield, traceable not only to the supply of water itself but also to the part that moisture plays in making nutrient materials available.

(*b*) Timing of maturity of crops—particularly desirable where earliness is profitable.

(*c*) Maximum table and market quality. Quality in the salable product is almost always materially improved.

(*d*) Utilization of land. Irrigation usually affords an opportunity for fuller employment of land.

(*e*) Protection against frost. Water is a great equalizer of temperature. It has high specific heat; that is, a pound of water gives off more British thermal units (B.t.u.) of heat in losing a degree of temperature than any other substance. Also, for every pound of free water present, 144 B.t.u. of heat must be given off before it can freeze. This is the latent heat of freezing or melting. Furthermore, all free water present must be frozen at 32° F. before plant juices can freeze at, say, 30° F. Thus, sprinkler irrigation kept going on a frosty night may effectively combat as much as 4 or 5 degrees of frost.

For irrigation to be profitable, advantages must be reflected in increased value of the crop. Naturally, irrigation can hardly be undertaken soundly unless the matured crop possesses a fair dollar value. Processing crops have not often been irrigated in the middle west and east because the value per acre is low. At the same time Jersey farmers have long been irrigating peas, and profitably especially in view of the fact that the crop is off the ground by the first of July. Erwin and Haber (see *Iowa State Bul.* 308) give results of experiments showing increases due to irrigation as high as 200% and even more.

The value of irrigation must be considered not on the basis of a single rainy or very dry year but upon an average of several years. Weather Bureau records can help greatly.

Critical times. There are two times in the life of plants when adequate water supply is especially important. The first is when the plants are just starting, either germinating from seed or establishing a new root system in the soil after being transplanted. The quantity of water used by the plants at this time

is not large; but, since the water-gathering system is limited, an adequate supply of moisture in the soil is very important. The other time of maximum need is when the plants have become large, are growing fast, and have an enormous evaporation rate. When an acre of cabbage is gaining weight at the rate of half a ton or more a day, the water that goes through the plant would make quite a stream if we could see it.

WATER SUPPLY

Some farmers have spent good money installing irrigation systems only to find that sufficient water was not available. Supply must be gauged by drouth years and not by rainy years.

Sources

Irrigation water is derived from many sources.

Streams. The simplest source is by diversion of a stream coming from higher land to irrigate by gravity a fairly level area of lower land. This principle furnishes water for great regional irrigated areas such as the Arkansas and South Platte Valleys in Colorado. Irrigation companies or cooperatives maintain canals many miles long and allot water to farmers who, as members of the company, pay on a basis of acreage or acre-inches. Details of these vary widely, but western states have an extensive body of law dealing with water rights and organization. Many projects are operated by state or federal governments.

Much irrigation water is pumped from near-by streams for the individual farm. Good movable pumps are now on the market. Under USDA Soil Conservation programs many farm ponds have been constructed with irrigation as one of their uses.

Wells. Where the water table is near the surface, driven wells are widely used. They consist merely of a piece of pipe sharpened, perforated, and driven into the ground. Special tips for this purpose may be purchased. Some gardeners have many such wells and use portable pumps. In the great Salinas area of California, most of the water is from wells, some as deep as 700 feet, drilled and cased and equipped with powerful electrically driven pumps. Artesian wells furnish much of Florida's irrigation water. Wells, casings, and pumps are expensive. Re-

ceding levels of ground water have increased costs of irrigation from wells in many areas.

Pumps

Most pumps nowadays are rotary rather than reciprocating. Great care is necessary to have pump and power adequate for the task. This is an engineering job, but reliable irrigation and pump companies can give good service. Also, one may consult the agricultural engineers at the state college.

Pipe versus ditch

Water is carried from pump to growing plants by pipe or open ditch. The ditch is cheaper but more wasteful through seepage and evaporation. Pipe, of course, is necessary where pressure distribution is employed. Ditches are sometimes lined with cement, and water may be carried short distances in wooden or iron flumes.

DISTRIBUTING SYSTEMS

Water is applied to land in three general ways: (1) by surface flow; (2) by overhead sprinklers; (3) by subirrigation.

1. Surface flow

Water from ditch or pipe is released at the edge of a field or part of a field. Under the *furrow* system (see Figs. 12.3 and 12.4), it is conducted in ditches across the ends of the rows or beds and released into furrows between single rows or between narrow beds, usually made up with two to four rows of the crop. Water is let out of the ditch by cutting its side with a shovel. Many now use short pieces of pipe or siphons to avoid the washing incident to open flow. Under *flooding* systems (Fig. 12.5), water is led into nearly level beds, enclosed by a low bank of earth, and the whole surface is covered. Flooding is often used for field crops but seldom for most vegetables. Texas onions and spinach are commonly irrigated by flooding.

Leveling. Surface irrigation requires fairly though not perfectly level land. A slope of 4 to 12 inches per 100 feet is desirable in furrows. In some sections, great volumes of earth are moved with heavy grading equipment. This, of course, may not be done where surface soil is shallow. In some sections as in

Fig 122 (*Top*) Gate in ditch adjusted and locked to permit flow of a definite amount of water to a given farm

Figs 123, 124 (*Bottom*) Last two steps in the distribution of water by the furrow system The same method may be used in the home garden

Dimmit County, Texas, the land is laid out on contours for convenient irrigation as well as for erosion control.

Operation. Surface irrigation demands little equipment but much time and skill. With furrow distribution, water is admitted to one or a few rows fairly rapidly until the end of the row is reached. Then, flow is checked so that water is absorbed the whole length of the row. When enough has been applied, the supply is cut off. Meantime, other rows have been started, and so the work progresses.

FIG. 12.5. Flooding irrigation on contour beds of onions in Texas.

Water spreads through the soil by gravity seepage and to some extent by capillarity. Sidewise movement is spoken of as "subbing out." If soil is coarse and porous, waste of water by downward seepage is serious not only in itself but also because it leaches away nutrients.

Surface irrigation is practiced on a wide variety of soils. It is often said that eastern soils are too heavy or too light for furrow irrigation, but actually little is known about its application under eastern conditions. There are probably many areas of fairly level land where it could be used to advantage. Experiments and practical trial of the method are needed.

2. Overhead systems

With overhead systems, water is carried under pressure in pipes and applied by means of nozzle lines or rotary sprinklers.

Nozzle-line irrigation was devised by Mr. C. W. Skinner of New Jersey in the early 1900's. See Fig. 12.6. The land is equipped with water mains. Then, lines up to 600 feet or more long are installed about 50 feet apart. In each line, very simple brass nozzles are set, perfectly aligned, 3 feet apart. With pres-

sure of about 35 to 50 pounds, water is thrown about 30 feet. Water-driven oscillators are available to turn the lines.

To apply an inch of water by this system usually requires 8 to 10 hours. Loss by evaporation is probably rather heavy as the fine spray passes through the air. Lines may be supported upon pipe posts, iron fence posts, or wooden posts, or they may be movable, resting on the ground or on crates.

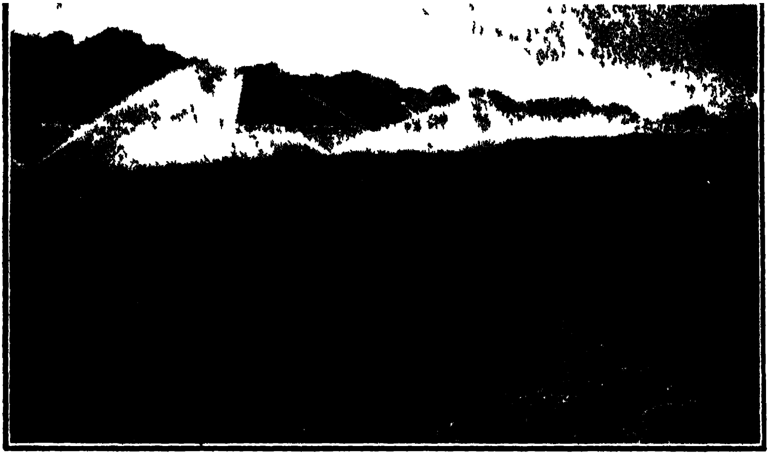
C W Skinner

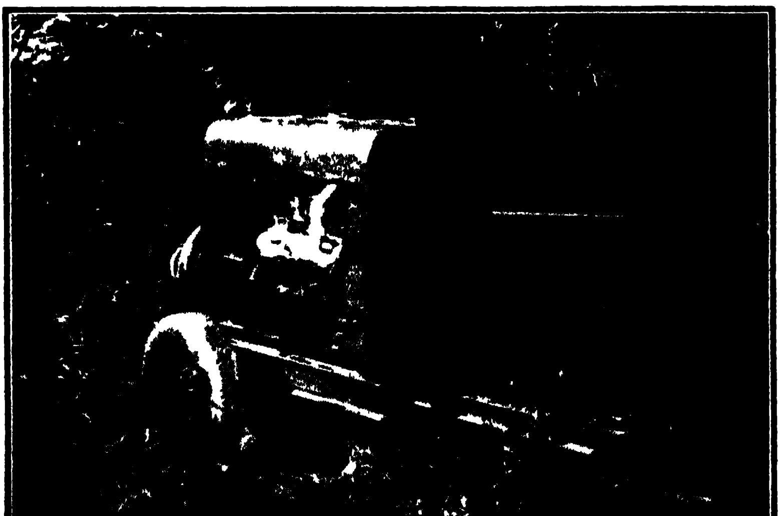
Fig 12 6 Oscillating nozzle-line irrigation supported on movable stands Note water-driven oscillator at end, also hose connection

Perforated aluminum pipes (Perfo-rain), laid on the ground, afford a simple and effective means of water distribution.

Rotary sprinkler systems. See Fig. 12.7. To overcome the disadvantages of surface irrigation, rotating sprinkler devices have been developed and are widely used in all parts of the country. Careful study of the spacing of sprinkling heads and lines has made possible a fairly even distribution of water, and light wind movement tends to smooth out such irregularities as may persist.

Sprinkler heads carry two nozzles, one applying water to the inner part of the circle and the other to the outer. These heads represent the results of refined engineering design to achieve even distribution under variable pressures and to turn the heads at the appropriate speed with minimum disturbance of the stream. Slow turning favors good absorption by the soil.





Marlow Pumps

FIG 12 7 Portable pumping unit for sprinkler irrigation.

Spacing. Practices vary in the spacing of sprinklers and lines, but 40 feet between sprinklers and 60 feet between lines is a fairly common arrangement. Sprinklers are made to cover circles of varying sizes, around 100 feet in diameter being fairly common.

The rate of application is rapid, an inch of water being commonly applied to an acre in two hours. This reduces evaporation loss while the water is in the air. Slow turning of the heads affords time for water to be fairly well absorbed between wettings of a given spot, and so puddling is reduced to a minimum.

Installation. Almost all rotary sprinkler installations are portable, making use of light-gauge pipe of large diameter. For example, two men can handily carry two 20-foot lengths of 4- or even 6-inch pipe.

Pipe joints are of the bell-and-spigot type with special clamps and rubber gaskets which become water tight as soon as the water is turned on. The movability of equipment and the rapid application of water make it possible to take care of a large area with minimum investment.

Rotary sprinkler systems are not well adapted to small plots. The cost per acre varies widely according to the length of the lines and the area to be served.

3. Subirrigation

Where an abundant water supply is available and where the land is underlaid with an impervious hardpan, subirrigation is feasible. Many areas in Florida are supplied with artesian water in this way. Tiles are laid at regular intervals, and water is fed into them from headers. On muckland subirrigation is sometimes effected by damming outlet ditches and so raising the water level for an area.

MANAGEMENT OF IRRIGATION

Irrigation is not a matter for rules and regulations. Every situation requires thorough knowledge, thoughtful judgment and skillful handling. Hence, it is necessary to recognize certain facts and principles about water and plants and then to make decisions to fit one's special case.

The role of water in plants. Water has four important parts to play in the life of a plant:

1. Water constitutes as much as 90% or even more of the plant substance.

2. Water maintains the form and position of younger stems, leaves, and flowers of plants; that is, osmotic pressure within the cells maintains *turgor,* which enables them to keep their shape like a water-filled rubber bag. Since cells are built and cemented together like stones in a wall, the whole structure stands. When water is lacking, turgor is reduced, the cells partially collapse, and the tissue wilts. Trees, well-advanced cornstalks, and some other plant structures are supported by tissues that have attained mechanical strength independently of turgor.

3. Water is the great solvent in which plant processes take place and in which substances are transported within the plant.

4. Water is one of the raw materials for the process of photosynthesis.

Vast water demand. In most crop plants, from 500 to 1,000 pounds of water pass through for every pound of dry matter produced. Thus a 15-ton crop of tomatoes, which is a good yield for an acre, might be roughly estimated as transpiring 2,000,000 pounds of water, a weight equal to that of the upper 8 inches of soil of the acre in which they grew. An acre-inch of water is about 27,000 gallons or about 200,000 pounds. Thus the plants use around 10 inches of rain, not taking into account run-off and evaporation from soil or weeds, if any.

How much water is needed? In the east, it is often assumed that most crops will grow well if they get an acre-inch of rain per week, but many factors may modify this estimate. A rough guide in irrigation is to make up the difference between desired and actual. An inch at a watering is common. In most western sections, water is used far more liberally than this, often with heavy waste. Heavy soils take water more slowly than sandy soils but may be watered more heavily at one time without waste. Loss of nutrients by leaching is to be avoided.

Practical irrigators frequently dig into the soil and judge its dryness by appearance and feel. Soil should not be allowed to become very dry before watering as distribution is faster and more uniform when the soil is slightly moist.

Judging dryness of soil. In considering irrigation management, two landmarks of dryness or wetness of soil are recognized. One is called *field capacity:* the soil contains all the water it can hold against gravity or drainage. The other is *point of permanent wilting:* the soil is so dry that a plant, wilted at the close of the day, will not be able to recover turgor *by morning,* or *until water is supplied.* Field capacity ranges from about 4% to about 24% of dry weight of soil—lowest in sand, highest in clay. Wilting percentage ranges from 2.6% to about 14% for the same soils.

When does a plant suffer drouth? There is experimental evidence to support the idea that a well-established plant is able to take advantage of soil moisture just as well when the supply is reduced almost to permanent wilting as when it is at field capacity. The original work by Veihmeyer and associates[15] was carried out with orchard trees which have a permanent and well-distributed root system. Experiments[5] with alfalfa, tomatoes, and other crops support the same principle. There seem to be some limitations in its application to crops. Practical operators do not seem ready fully to accept the principle in application to crops with small root systems like celery, carrots, onions, and lettuce.

It is now accepted that capillary movement of moisture in soils does not extend very far from a point where free water is present. In other words, roots grow out to the water rather than water moving to roots, save by gravity. Hence it is possible that there may be a good *average* amount of water in a block of the soil at the same time that available water may be down to the permanent wilting level at the point where the roots actually are. Under such conditions irrigation is needed.

Measuring water needs.[3] Studies are in progress designed to reveal methods of measuring water needs of soil. Observations on rate of evaporation either from a porous porcelain bulb, or *atmometer,* or from a free water surface have been used.

The *tensiometer* is a device consisting of a water-filled porous porcelain bulb, buried in the soil, and connected with a column of mercury. The drier the soil, the higher is the reading on the mercury column. The action of the instrument is based on the drawing tension between the soil and the water within the porcelain, which increases as the soil becomes drier.

Standardized gypsum blocks, each fitted with electrodes, may be buried in the soil. The material comes to equilibrium with the soil moisture, and a Wheatstone bridge measures the electrical resistance, which in turn is a measure of the water content of the soil. The gypsum blocks are more satisfactory in dry soil, tensiometers in wet soil.

Size of drops. Levine, in New York, has found that water pressure greatly influences the size of drops in sprinkler irrigation. Low pressure yields large drops, which in turn reduce the rate of infiltration into the soil and damage the physical characteristics of the soil.

SOURCES OF INFORMATION

Installation of commercial irrigation calls for careful design to fit the particular job in hand. A slip at one point may easily wreck a good irrigation enterprise, with loss of money and failure to achieve expected benefits. This often hurts a whole neighborhood by giving a "black eye" to irrigation where it is needed and could be very useful.

Knowledge of plants and their needs should be combined with competent engineering skill.

WEEDS AND CULTIVATION

Weeds

Weeds may be roughly defined as plants that grow where they are not wanted. They harm vegetable crops by competing with them for the available supplies of water, nutrients, carbon dioxide, and light.

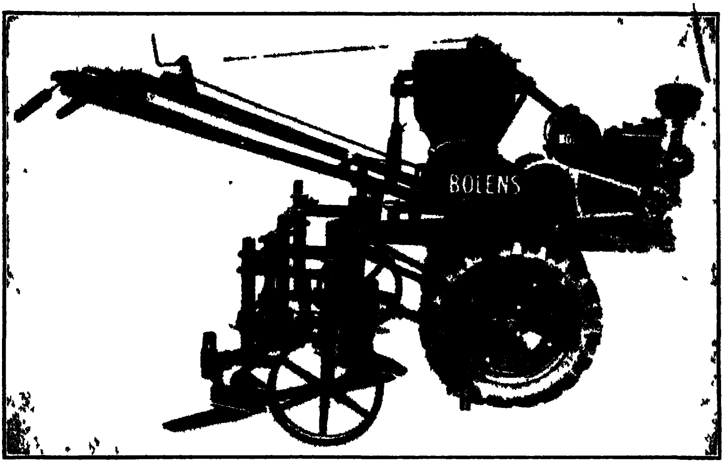
Weeds reduce both yield and quality of crops, increase cost of production, and often harbor insects and diseases to plague the crop plants. They are a great nuisance in and along irrigation and drainage ditches.

The time to kill weeds cheaply and effectively is while they are small. If weeds are allowed to mature seed, the task of control is more difficult in following years. Some farmers, by skillful and persistent care, are able to keep weed competition to a minimum.

Cultivation

In the broader sense all agriculture is cultivation of soil and crops. Cultivation in its narrower and special sense refers to stirring or tilling of soil between rows and in the rows of crop plants. This is still the principal means of controlling weeds among planted crops.

Cultivation may be accomplished by hand with rake or hoe. The scuffle hoe is very useful on muck and other light soils.

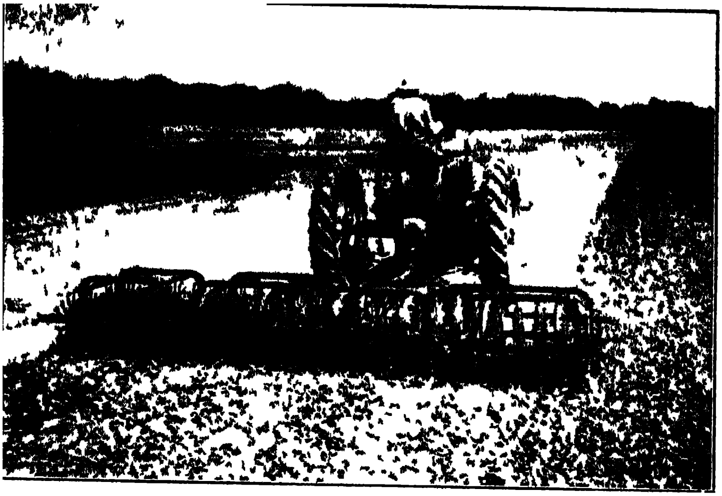


Bolens Products Company

FIG. 12 8 Cultivator blades instead of teeth do little damage to roots but destroy weeds effectively Note hopper for fertilizer side dressing or for band placement when using tractor for planting

Next comes the wheel hoe, operated by man power, and the small motor cultivators; then the one-horse walking cultivator and the two-horse riding cultivator. (Horses and mules still exist!) In large-scale operations, gangs of cultivators nowadays are mounted directly on a tractor though occasionally they are carried on a separate wheeled frame.

Cultivation tools are of many forms. Few gardeners have examined catalogues carefully to select just the type that is best for their special needs. In general, the tools should destroy all the weeds, should cut close to the plants, and should not injure the roots of crop plants or bring moist soil to the surface to dry out. In general, blades that skim just below the surface of the



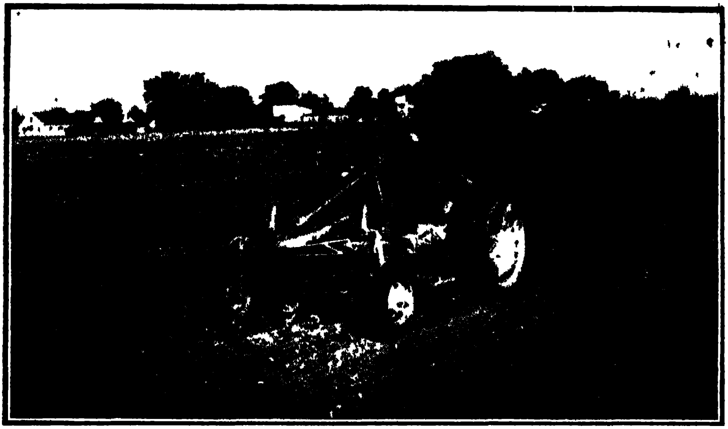
John Deere Company

Fig 12 9 Rotary hoe goes right over rows of corn breaking crust, killing weeds, and doing negligible damage

Ill Expt Sta.

Fig 12 10 Spring-tooth weeder, used in same manner as rotary hoe

soil are better than teeth. See Fig. 12.8. Some gardeners use teeth when weeds get out of hand and drastic action is needed. There are also tools that combine the characteristics of blades and teeth. Rotary tillers, with teeth on a powered shaft, are used where soil is suitable. The spring-tooth weeder, the rotary hoe, or even a spike-tooth harrow may be used when plants are small, covering the ground regardless of rows. See Figs. 12.9 and 12.10. Working when plants are slightly wilted, as at mid-day, helps to minimize injury.



Allis Chalmers Manufacturing Company

FIG. 12.11. Rear-engine tractor permits operator to watch the work.

Hoeing and hand weeding. In commercial fields, hoeing and hand weeding have been eliminated or reduced to a minimum. When practiced, they often go together, and, with certain crops, thinning is handled at the same operation. With labor as costly as it is, much ingenuity is exercised to avoid all hand work. This involves good general control of weeds, accurate planting of seed, straight rows, and close cultivation. A vigorously growing crop such as bush beans will not give much chance to weeds in the row. At the same time, some hand work is a good investment to prevent weed plants from going to seed.

L. H. Bailey in *The Harvest* writes about his father's hoe, which he still possesses. "Clish, clish, clish in an even rhythmic subdued cadence the hoe moved up and down the rows, never chopping, never hacking, never faltering, for my father was a hoeman as another man might be a welder or a wheel-wright,

taking pride in the skill of his handiwork." Doctor Bailey knows how hoeing should be done, never chopping, never hacking, but slipping smoothly just under the surface of the soil. For good work a sharp hoe is required, and the all-day worker should have a file in his pocket.

When hand weeding is necessary, previous wheel hoeing or cultivating should cut away all but a very narrow strip near the plants. Frank Miller, a veteran onion grower, adjusted his wheel hoes to leave a strip only an inch in width. Then the hand work was easily and rapidly done. Small hand weeding tools are useful with small crops.

Cultivation is sometimes planned to throw earth into the row to cover and smother little weeds and so to save hoeing and pulling. This should be managed so that roots will not be cut.

Why cultivation pays

Much experimental work and discussion have been focused on the question whether stirring of the soil by inter-row cultivation is or is not beneficial aside from weed killing. It was long held that maintenance of a soil mulch was useful in conserving moisture. H. C. Thompson [10] and his associates conducted extensive experiments on the subject, comparing (1) no cultivation with weeds uncurbed, (2) scraping to destroy weeds but without stirring the soil, and (3) cultivation with stirring and formation of a soil mulch. Weed control naturally proved of major importance, but comparison between scraped and cultivated plots showed only minor differences in (1) moisture content of the soil, (2) aeration, (3) soil temperature, and (4) nitrification. Experimental results elsewhere supported these findings. More recently, with the advent of chemical weed control, the matter is being restudied, for there are indications that even very light stirring of soil may have a beneficial effect, as yet unexplained.

Cultivation after a light rain is likely to hasten the evaporation of that moisture rather than to conserve it. One who lays out a few pounds of seed to dry will stir it frequently to speed the process. It is so with soil. In fact, harrowing often hastens drying of a soil surface so that seed may be planted sooner than otherwise.

Cultivation may retard run-off of a gentle rainfall but may favor erosion in a heavy one.

Ridging. Heavy ridging of rows is generally not good practice unless required for irrigation or drainage. It not only cuts roots but it also increases the evaporating surface of the soil. Potatoes may well be slightly ridged to prevent exposure of tubers and to make digging easier, but moderately deep planting will usually take care of this. Ridging is more necessary in heavy than in light soils, but it should never be overdone. With corn, moderately deep planting will help to prevent plants from blowing over.

Other weed controls. Seed may be planted rather deeply but only partly covered at the time, filling in after plants are nicely above ground, thus covering little weeds as they germinate.

When a field is badly infested with weed seed, it is well to prepare the land a week or two ahead of need. Then many weeds will germinate and may be destroyed just before planting.

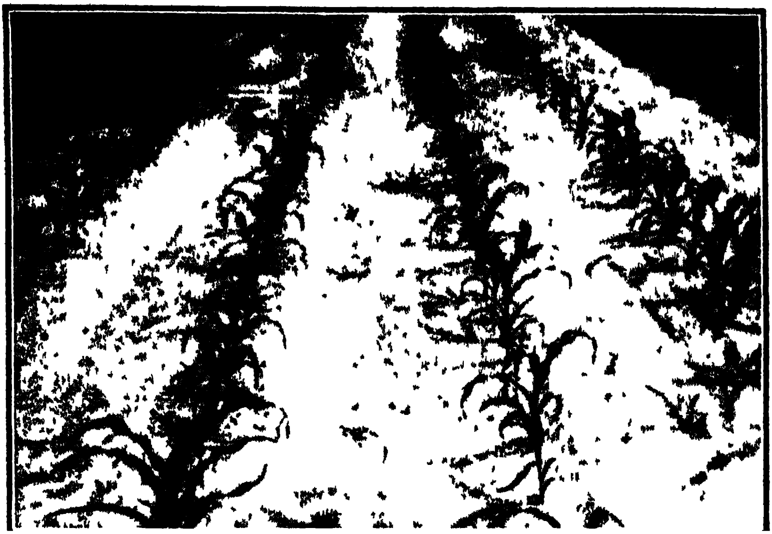
When cover crops are grown, a good stand and favorable conditions for vigorous plant growth are helpful in preventing weed growth.

Hedge rows, ditch banks, and strips between fields are great harboring places for weeds as well as for insects and diseases. They should be eliminated or kept clean, as should odd bits of land around buildings and elsewhere; mischief breeds in idle spots of ground.

CHEMICAL WEED CONTROL

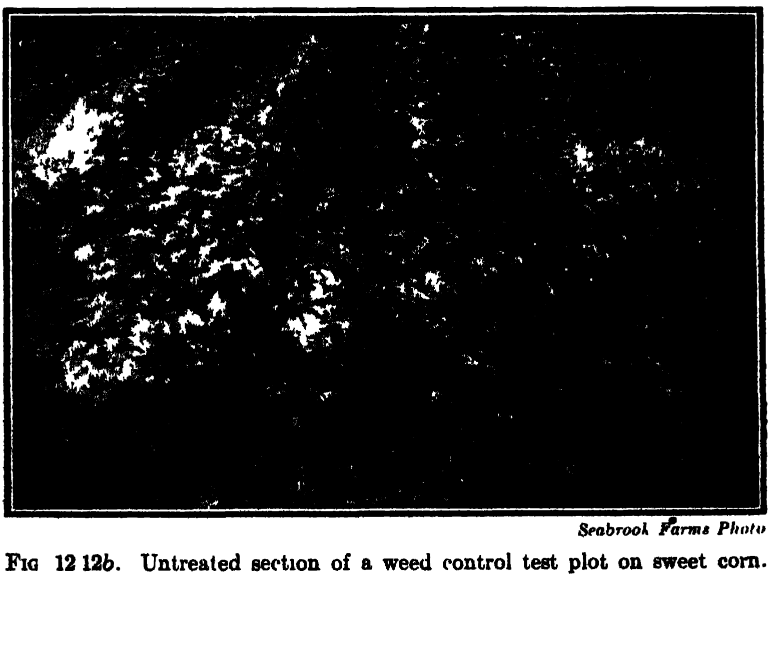
Although sulfuric acid and several other materials have been used to kill weeds for many years, chemical weed control on a commercial scale is relatively new. The discovery that the growth regulator 2,4-D would kill most broadleaved plants and not grasses aroused world interest and stimulated research for other materials. Just as there are insecticides and fungicides for specific insects and diseases, there are herbicides for specific weeds and crops. This discovery that certain materials are *selective* in their action has given great impetus to chemical weed control. Some materials are selective because they do not stick, some because of differential absorption, some because certain plant groups are not sensitive physiologically.

Time of application is of prime importance in using chemical weed killers. Some materials, because they are toxic when in



Seabrook Farms Photo

FIG. 12.12a. Treated section of the sweet corn weed control plot. Corn in light, sandy soil was sprayed with 2 pounds per acre of CRAG Herbicide 1 on June 27, photographed July 17.



Seabrook Farms Photo

FIG. 12.12b. Untreated section of a weed control test plot on sweet corn.

direct contact with the plant, must be applied *before* the crop emerges from the soil. This is termed a pre-emergence application. Other chemicals can be applied post-emergence, i.e., after the crop has appeared above ground. Use of herbicides requires careful following of directions and allowing for various factors such as soil moisture and size of plants. Following is only a brief outline for some of the materials that are available. See current literature.

2,4-D (2,4-dichlorophenoxyacetic acid) is a plant growth regulator. It can be used for controlling weeds in sweet corn and asparagus. Do not expect it to give good control of grassy weeds. Extremely small quantities either as spray drift or residue in tanks are harmful to most vegetables and ornamentals. The toxic effect persists in the soil for about two weeks.

Stoddard solvent, a hydrocarbon, lighter than gasoline, widely used as a paint thinner and dry-cleaning fluid, will control practically all weeds in fields of carrots, parsnips, and other members of the Umbelliferae family. It can be sprayed directly on the crop, preferably when weeds are small. This oil may also be used as a pre-emergence spray for several seeded crops. Its residual effect lasts about three days.

Dinitros, of which there are several types, such as Sinox PE and Premerge, are most useful as selective weed killers for peas and as pre-emergence herbicides for beans and potatoes. These are coal-tar derivatives with a toxic persistence in the soil of approximately four days.

Potassium cyanate, in conjunction with a pre-emergence application of cyanamid dust, has given good control of weeds in onions. Results are influenced greatly by size of weeds, weather previous to spraying, and age of the onions.

Salt solution, common sodium chloride, is a good weed killer for beets because it does not adhere to the waxy leaf. If the weeds, however, are also waxy, control is ineffective. It has been used with success in areas where mustard predominates.

IPC (isopropyl N-Phenyl carbamate) and **chloro-IPC** have appeared promising as pre-emergence weed killers for spinach.

Sodium 2,4-dichlorophenoxy ethyl sulfate (Crag Herbicide No. 1) is related to 2,4-D and most effective as a weed seed germination inhibitor for asparagus and strawberries. On both these crops it may be applied after emergence.

Phthalamic acid (Alanap) is a selective herbicide for the vine crops and should be applied to melons, and cucumbers, just as weed seeds are beginning to sprout.

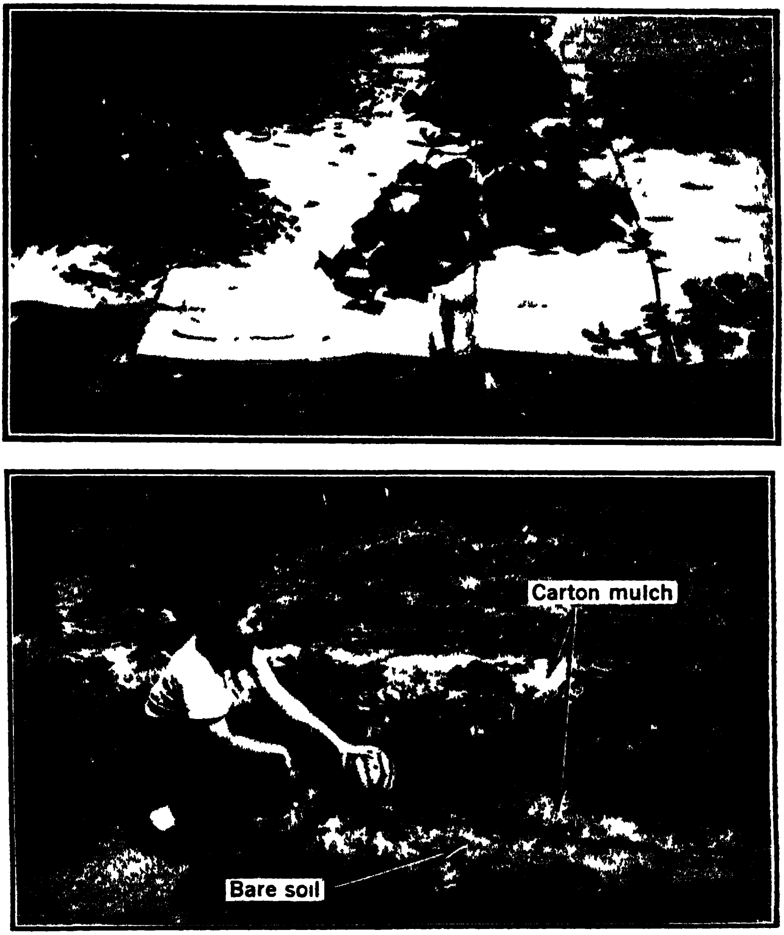


FIG 12 13 Mulching controls weeds and conserves moisture Here paperboard cartons are used for watermelons which matured well under northern conditions Note wires to hold cartons in place

Weed control research goes forward apace, and new compounds and methods appear every year Among promising chemical weed killers are CMU, TCA, NIX, and pentachlorophenol.

Chemical weed killers have gone a long way in eliminating the need for hand weeding. They should be regarded as tools to aid in the control of weeds, not as miracle materials to eliminate the tractor cultivator.

Mulching

Soil, especially for tomatoes, may be covered with leaves, coarse manure, or straw. Sawdust and shavings (see page 171 and ref. 10.18) once considered harmful to soil has proved a good mulch material. In the home garden, paper, carton board, and aluminum foil have been used effectively. Fertilizer bags serve well. These materials may be held down with wire arches.

Mulch conserves moisture, prevents growth of weeds, keeps plants and fruits clean, and is beneficial in hot climates in keeping the soil cooler than otherwise. Plants under mulch of humus-making material sometimes show yellowing, suggesting shortage of available nitrogen; ample nitrogen supply is a wise precaution, although it is not quite clear why this effect should result when mulch is not incorporated in the soil.

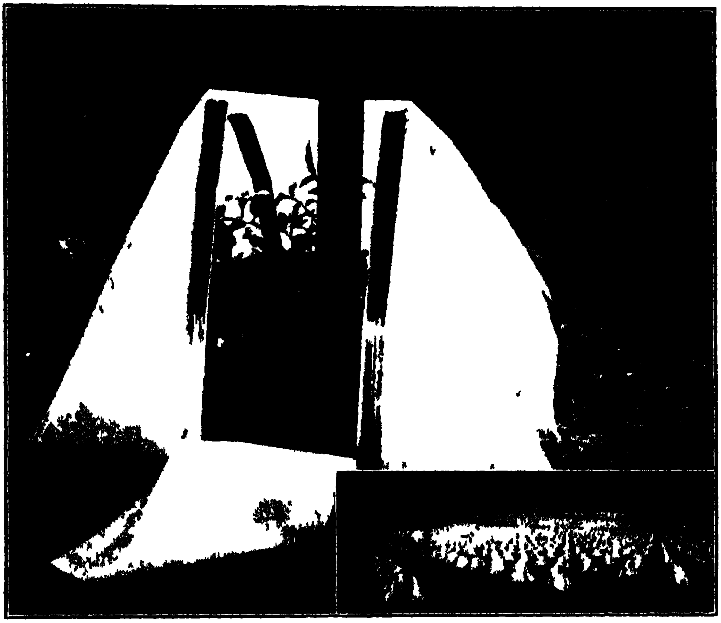
PLANT PROTECTORS

It is great fun to see how early one can have various products ready to eat or sell. It is more than fun, for it lengthens the season of fresh vegetables for the table and it often brings good money return through relatively high prices at a season when income is low. Various forms of plant protectors may be used (1) to promote growth, and (2) to ward off frost and other injury which may be caused by insects or by wind and driven soil.[11]

Paper protectors. One of the simplest and cheapest ways to make plant protectors is to get waxed bleached kraft paper of about 70-pound basis weight, cut to about 16 by 18 inches Two conical forms about 9 inches in diameter, 6 inches high, and with tops cut off, are made in a tin shop, one a little larger than the other. The smaller is mounted on a piece of plank, say 16 by 24 inches. A sheet of paper is put over this and creased and pressed quickly into form. Then paper and upper form are lifted and put over the place where the seed has been planted or a plant has been set. With trowel or hoe, earth is pulled over

the protruding flaps of paper and the form is lifted. Thus is built a little paper greenhouse which withstands wind and weather for several weeks.

Commercial concerns make protectors like these in various sizes and forms. The larger ones are tall enough for tomatoes. See Fig. 12.14.



Germain Seed and Plant Company

FIG. 12.14. A huge protector for tomato. Two plants are set a foot apart to be trained single stem. The next interval is 2 feet. Inset: Plant protectors in a western melon field.

A huge acreage of very early cantaloupes is grown in the Imperial Valley in California* with paper protectors over the hills and with elaborate windbreaks of brush, wire, and paper for additional shelter. See Fig. 22.4.

Another form of protector for closely planted vegetables consists of a tunnel of the same kind of paper, unrolled over round

* Look this up on a map of the United States. It is one of our greatest vegetable-growing districts. Brawley and El Centro are the principal towns.

wire arches about like those used in croquet, and held in place by drawing earth over the edges.

Cold frames used for plant growing are often planted to commercial crops just after they are vacated. Crops that benefit by extra heat in the spring are beets, celery, cucumbers, muskmelons, eggplants, and peppers. At Portsmouth, Va., in Orange County, New York, and near San Diego, Calif., this method is practiced on a large scale.

Management. Considerable care must be exercised in the management of plant protectors. Soon after plants are set or after seedlings come up, they must be ventilated by making holes in the paper or otherwise opening them. The holes can be made small at first and larger later on. If this is neglected, the plants are unhardened and may become spindling and unproductive.

Experiments. Most of our knowledge of the value of plant protectors has come by cut-and-try experience. Nissley (see references 1 and 5 in Chapter 9) and Ware[11] have reported on experiments testing growth-promotion value.

Data are lacking as to just how much protection against frost may be expected; a guess would be 4 to 6 degrees, depending upon the duration of low temperature, wind, and other factors.

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13

Insects and Diseases

Most vegetable plants are beset by many kinds of enemies, each of which requires its own specific measures of control. Related diseases or insects may be combated by similar means, but treatments must be chosen in the light of definite knowledge of the nature of the enemy and the available resources. Methods vary considerably in different parts of the country.

This chapter is introductory and general. Further information will be found under the various crops. Consult references for fuller information.

The constant development of countless new materials and methods makes it essential to consult current publications and local specialists.

KINDS OF ENEMIES

The principal enemies of plants may be grouped as follows:

Diseases	*Animals*
Fungus	Insects
Bacterial	Nematodes
Virus	Slugs and snails
Physiological	Arachnids (mites, etc.)
	Other animal forms

Weeds, see Chapter 12.

The fungi,* with the algae, are plants of the great group of Thallophyta. The fungi are simple in structure, not highly specialized, without a vascular system and without chlorophyll Thus, they must gain their food (carbohydrate or carbohydrate derivatives) from other organisms. The disease organisms are parasites, preying upon living things, in this instance on plants.

* Fungus (pl., fungi).

Bacteria, important disease organisms, represent one of the five groups of fungi. They are single celled and multiply solely by division.

Virus diseases were so named because they can be transmitted from one plant to another by transfer of juice. It has not been possible to separate an organism or active principle from the liquid by filtering, as with bacteria and fungi, the filtered juice being capable of carrying the disease. The exact nature of the virus is still uncertain. The current view is that viruses are complex molecules, perhaps protein-like, which may occupy a border zone between living and non-living matter. A group called "Rickettsia" is now recognized, with properties between those of virus and bacterium. A common symptom of virus diseases is a mottled appearance of foliage; hence, they are often called mosaic diseases. They may also occasion abnormal growth as dwarfing, witches brooms, and skeletonized leaves.

Physiological diseases are not traceable to any causal organism but are due to some failure in the functioning of the plants. If water fails to reach the edges of leaves, as in potato, the tissue breaks down and tip-burn occurs. Blossom-end rot of tomato is another illustration.

The insects represent one of the great groups of animal life, containing vastly more species than all others together. As enemies of plants, two groups of insects are noted: the sucking and the biting. This distinction governs the control measures.

Nematode worms, belonging to an animal group lower than the insects or the molluscs, infest roots of greenhouse plants in the north and many kinds of plants in the south, forming root knots and cutting off passage of water through the plant.

Slugs are snails belonging with the molluscs, which include oysters, mussels, and other shellfish.

The Arachnids include the mites that are especially troublesome in greenhouses: eight-legged cousins of the spiders.

Many birds and other animals are troublesome at times—crows, pheasants, blackbirds, moles, rabbits, raccoons, and others.[12]

CONTROL MEASURES

The enemies of plants are so varied that no general set of directions can be offered even for a single insect or disease. The

grower must observe certain principles and then depend upon books, bulletins, or the advice of the county agricultural agent to know what is best to do about a given enemy on a given crop in a given locality.

General precautions

1. **Let the operator beware.** Some insecticides and fungicides are dangerous to the user. Follow directions with care, even if it is something of a nuisance. Actually few have suffered if this is done. See page 248.

2. **Prevention is always better than cure.** Once a fungus begins to grow within a plant, almost nothing can be done. Fungicides kill before entrance to the plant tissue. Many fungi, all viruses, and some insects are impossible to control directly; for them, prevention is the sole defense. Prevention is usually cheaper than direct treatment.

3. **Timeliness.** Constant alertness is necessary to detect the onslaught of an enemy. Blanket measures, carried out without regard to the presence of a disease or insect, are likely to be wasteful and overcostly. Treatments after an attack has gained headway are usually futile. Timely treatment when conditions favor a disease may forestall serious damage. Thus spraying as soon as cool, moist weather sets in may ward off an attack of late blight of tomatoes which is favored by such conditions.

4. **Identify the enemy.** Countless questions like this are asked: "My cucumbers are dying. What spray shall I use?" Even if the query merely stated that the plants wilt down and die, there would at least be a clue and the answerer could guess what is likely in the region from which the questioner comes. It is not very difficult to become familiar with the various enemies of our crop plants that are common in a given area. Bulletins on insects and diseases describe the major symptoms. Then, if the farmer has further inquiries, he should write to the county agricultural agent or state specialist describing the trouble and sending samples.

5. **Thoroughness** is essential both for effectiveness and economy. Many a row of celery has been dusted on top when the blights usually begin on the lower leaves. Light but even distribution of dusts and sprays saves material and achieves results. Too many expect the crop to be saved simply because they have

performed a ritual by dusting or spraying. The insect that is missed lives on to do his damaging work and to multiply his kind.

General measures for control

1. **Select land that is free of enemies of the crop to be grown.** Some diseases such as clubroot of cabbage may persist for seven or eight years. Rotation of crops is helpful then.

2. **Dispose of hedge rows, weeds, and crop refuse,** which frequently harbor insects and diseases. Mosaic of muskmelons is often confined to the end of a field where there is a fence row containing catnip or milkweed or other plants subject to the same virus disease. Ditch banks harbor many enemies.

3. **Fall plowing** insures decay of refuse and destroys certain insects by turning them out to freeze after they have settled in winter quarters.

4. **Choose planting times** to avoid maximum danger of infestation. Many insects such as the onion maggot fly have rather definite egg-laying periods.

5. **Soil treatments** are effective in greenhouses and seedbeds against nematodes and fungi, especially those causing damping-off. See Chapter 9. Heating is the most common method, the kitchen oven being used for small quantities and hot water or steam or electric sterilizers * for larger quantities. Various movable pipe systems are used for steaming soil in greenhouses and plant beds, and some houses are permanently tiled for the purpose. Formaldehyde, methyl chloride, and chloropicrin are also used.

6. **Fumigation** of greenhouses, of storage room, and of stored seed is common practice. The list of materials is too long to be given here. See a book on insects.

7. **See that seeds and plants are free of enemies.** Plants for transplanting may carry aphids, clubroot, or nematodes. Seeds should, if possible, come from regions that are not infested. Bacterial blight of beans is one result of not heeding this precau-

* The word sterilization is commonly though inaccurately used. The term as used in a hospital means complete killing of all living cells. In reference to soil it involves only partial killing, sometimes called pasteurization. Beneficial organisms soon multiply again, and after a time the enemy is likely to recur.

tion. Seed-borne diseases may be destroyed by various treatments.

8. **Use resistant varieties or strains.** Some diseases, such as those caused by various forms of fusarium, can be effectively controlled in no other way. Cabbage yellows is an example.

9. **Traps,** consisting of electric lights over pans of oil, are used by a few growers against corn ear worm and tomato fruit worm, which are the same insect. **Hand picking** is effective on a small scale against such insects as the tomato horn worm.

10. **Screening** seedbeds and small garden plantings will keep off the striped cucumber beetle and the cabbage maggot, though calomel or chlordane treatment is now more usual for the cabbage maggot.

11. **Trap crops** may be planted before the main crop to attract insects, and then both plants and enemies may be destroyed. Thus summer squash may be planted between rows where late squash is to be planted.

12. **Adjustment of soil reaction** is effective against clubroot of cabbage and scab of potatoes, the soil being made about neutral for one and somewhat acid for the other.

13. **Parasites** hold some insects in check, but their artificial use is not yet common.

14. **Spraying and dusting** are the common methods of applying fungicides and insecticides to plants.

Fungicides

Bordeaux mixture was formerly the most important fungicide. Although other copper fungicides are probably still the most important for vegetables, organic materials, particularly carbamates, have proved highly useful. This can be attributed to better disease control in some instances and less crop injury in others. To avoid complicated chemical terminology and to avoid use of proprietary brand names, the following standard "nicknames" have been approved:

Ziram (a zinc carbamate sold as Karbam white, Zerlate, and others). Recommended for seedling disease control. More effective than copper for many vegetable diseases not including late blight.

Ferbam (an iron carbamate, sold as Fermate, Karbam black, etc.). Similar to ziram but possibly more injurious to tender seedlings.

Nabam (a sodium carbamate, sold as Thiodow, Parzate liquid, Dithane D-14, etc.). As effective as ziram against most diseases but also good for blight control of tomato or potato if applied at 4- to 5-day intervals.

Zineb (a zinc carbamate, sold as Parzate dry, Dithane D-78). Similar to nabam but with zinc added.

Captan (a phthalamide, sold as Orthocide-406). Close to an all-around fungicide. Recommended for seed treatment, seedling spray, and field application.

The use of thiram (arasan, tersan) and spergon as seed treatment is increasing in addition to the copper oxides.

Ethylene dibromide (Dowfume W-40 and Iscobrome D), methyl bromide (Iscobrome I and Dowfume MC-2), and others are being used as soil fumigants for combined nematode, disease, and weed control.

For more detail on chemistry and preparation of these control materials, consult special books.

Insecticides

DDT is effective against many vegetable insects, particularly worms or larvae. Because it is a poison it should be handled with care and not applied just prior to harvest on edible portions of crops.

Rotenone is useful against both sucking and chewing insects. It is found in the root of derris, cube, and timbo plants. Although less effective than several other insecticides, it is nonpoisonous to man in quantities needed to kill insects, and therefore is highly suitable for home garden use.

Phosphate compounds have been on the market only a few years. **Parathion** has been an excellent aphid killer. **HETP** and **TEPP** have much less residual effect. All are quite hazardous to humans if improperly used.

New hydrocarbon insecticides such as **chlordane, aldrin,** and **dieldrin** are closely related and have shown much promise in the control of soil insects such as cabbage and onion maggots and wireworms.

Pyrethrum, arsenicals, and **nicotine** are still used in many situations but have been largely replaced by newer materials.

Systemic insecticides are applied to plant or soil, enter the circulation stream, and so poison insects feeding on tissues or

juices. They are useful for non-food plants, but only have approval for use on food plants.

POISON RESIDUES

Many pest control materials, particularly insecticides, are harmful to humans and other warm-blooded animals if used improperly. Government controls are in effect to regulate the sale and use of potentially harmful chemicals. The Production and Marketing Administration of the U. S. Department of Agriculture through the Insecticide, Fungicide, and Rodenticide Act of 1949, has control over the labeling, use, registration, and reliability of these materials. No product can be sold legally without their approval.

In some instances, when a pesticide is essential for production, contamination is unavoidable. A maximum allowable content or tolerance must be determined. In 1950 the Food and Drug Administration, who control residues, called a public hearing to consider tolerances for newly developed chemicals. A report was released in 1954. It lists tentative tolerances for many of the common pesticides. These tolerances are official and are considered to provide a maximum degree of safety. Here are some of them:

	Parts per Million
Dieldrin, chlordane	0.1
DDT	7.0
Parathion	1.0

Manufacturers of baby food will tolerate no residue and often prescribe the insect and disease sprays that must be used.

Growers who follow carefully the directions given on the weed killer, insecticide, or fungicide label with respect to amount applied and time and method of application need not fear poisonous residues on their vegetables.

Practical solution of the poisonous-residue problem takes three forms:

1. Use non-poisonous insecticides after edible parts begin to develop. Poisonous materials, which are usually less expensive, may be applied in the earlier stages of growth.

2. Trim away as much as feasible of the outside leaves, which are more likely to carry poison.

3. In using poisons, spray or dust lightly and thoroughly.

SPRAYING AND DUSTING

The choice between spraying and dusting depends upon the crop, the enemies to be controlled, and many local circumstances.

Spraying requires a convenient and ample source of water and somewhat expensive equipment. Low-volume, low-pressure sprayers have been developed for the control of some insects.[9b] For example, 25 gallons of parathion spray per acre at 100 pounds pressure have given excellent control of bean beetles. High-volume sprayers use more water but are less disturbed by wind than low-gallonage sprayers or dusters.

Dusting is usually preferred for small-scale operations as well as for some large-scale enterprises. Equipment is cheaper and lighter, the load is lighter, and speed is greater. Wind-free periods, however, often occur only at dawn or late evening. Dusting is more exacting than spraying. It is generally just as effective if well done. If the job cannot be well controlled, spraying is to be preferred. Dusting is best done when the air is still and when dew is on the foliage.

Timing. Experience shows just what is the best time to apply the first treatment. If celery blights or tomato leaf diseases are troublesome year after year, dusting or spraying in the seedbed may be the most effective of all the applications made. With aphids, it is usual to await the first appearance of the insect, but this requires careful watching all over the field.

Applications must be more frequent if rain occurs and when new growth is rapid. In most potato-growing sections, fairly clear-cut schedules have been worked out. With crops that are not so important in a district, one must devise his own plan, using all the light he can get from reading and from extension workers.

Spreaders and stickers. Against fungi and chewing insects, the objective is to cover all surface thoroughly even though lightly. With sprays, certain materials cause the liquid to spread more readily and so give more perfect coverage. Various soaps

are widely used, which modify the surface-tension relations of the liquid, reducing the tendency to form droplets. Sulfonated oils and alcohols, casein or powdered skim milk, and flour serve as both spreaders and stickers. These materials are especially important in spraying smooth or waxy foliage as in the cabbage family.

Hoods. A trailing cloth or canvas behind a duster on wheels serves to confine the dust for a moment, increasing the chance of its reaching all insects and delaying dilution in the air. Hand dusters are often equipped with a little metal cone to hold over a hill of plants while a puff of dust is given.

Equipment. Sprayers and dusters are available in wide variety, from a shaker-top package, dust and all, for a quarter, up to a thousand-dollar ground rig or to an airplane. In buying, observe the same general principles as in choosing other mechanical equipment. See ref. 9 and Chapter 6.

Sprayers. Efficient spraying is in some degree dependent upon high pressure to break up the liquid into a mist of fine droplets

F. E. Myer & Bros. Co.

FIG 13.1. A small power sprayer.

and to agitate the air so that it swirls around, among, and under the leaves. Small hand or knapsack sprayers are weak in this respect, but good results may be achieved if the work is not done too rapidly and the nozzle is turned to shoot the spray toward the plant from several angles.

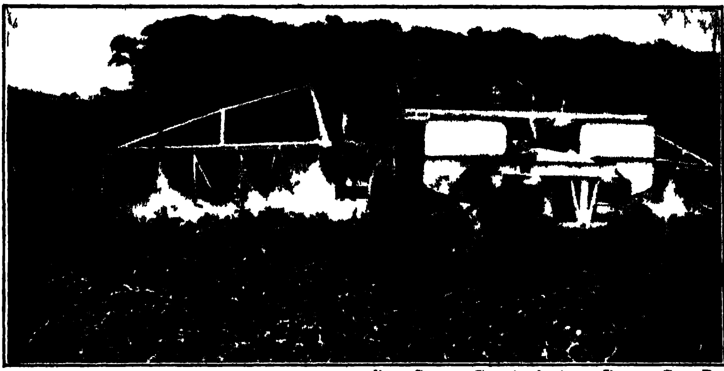
Larger sprayers are mounted on wheels or tractors. Some have hand pumps; others are powered by traction from the wheels. Larger rigs are drawn by tractor, and pumps are separately powered, or a power take-off from the tractor may be used to good advantage.

Dusters. The better makes of hand dusters work satisfactorily for the home garden. The knapsack and bellows type of

FIG. 132. Bellows-type, hand-operated knapsack duster.

duster and the rotary dusters, carried by shoulder straps and hand actuated, can be used even on commercial plantings; perhaps 3 to 5 acres a day can be covered when the plants are not fully grown.

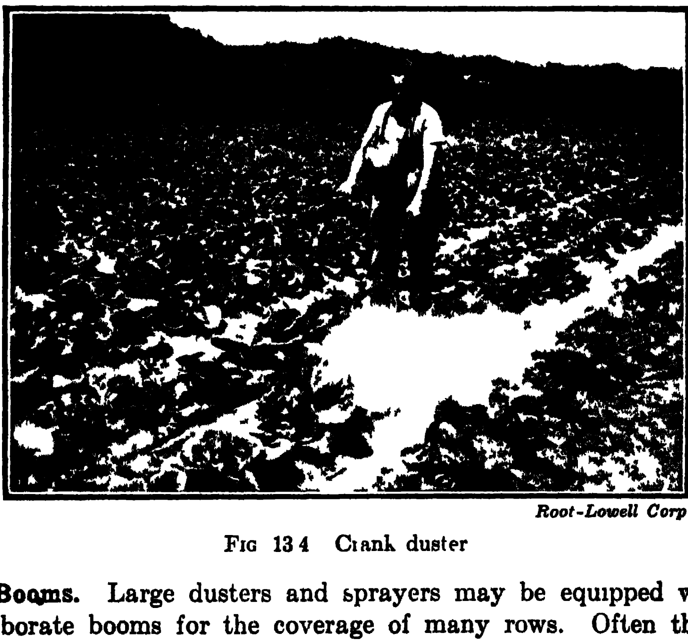
The rotary fan-type duster is adapted for continuous row work. Bellows dusters, lever operated, are single or double acting. The double-acting duster feeds dust on both up and down strokes.



Bert Shaw Co Agrl Agt Potter Co Pa

Fig 133 Great 8-row sprayers are used for potatoes many operated by cooperative spray groups or rings Note the tanks mounted directly on the tractor

Larger dusters are mounted on wheels or tractors in much the same way as sprayers Some are on tandem wheels to go between rows, and some are mounted on mule back.



Root-Lowell Corp

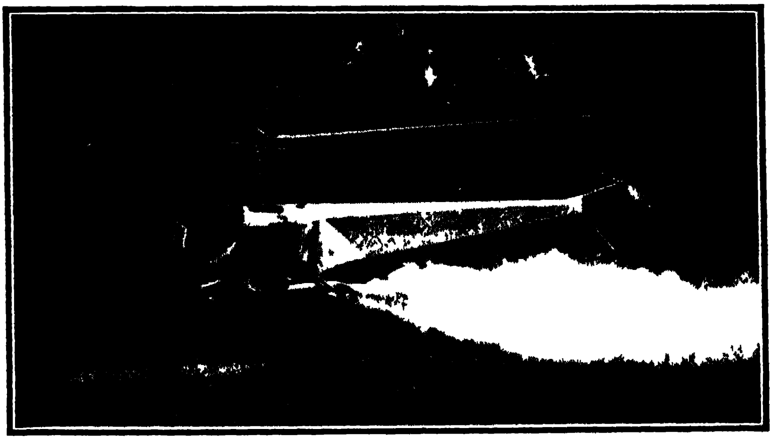
Fig 134 Crank duster

Booms. Large dusters and sprayers may be equipped with elaborate booms for the coverage of many rows. Often three nozzles are set per row, two adjusted to shoot upward from the

sides. In big fields, an acre or more may be covered in a single round trip.

Clogging of nozzles is forestalled by careful straining of water if necessary, by buying material of proper fineness, by care in mixing, and by careful rinsing of equipment after use. As nozzle discs wear rapidly and become inefficient and wasteful, they must be replaced frequently.

Airplane and helicopter dusting requires slow-speed planes and experienced operators who can fly low and avoid obstacles. The method is desirable when large areas are to be dusted quickly while the air is still and the dew is on.



Bell Aircraft Corp.

Fig 13.5. Helicopters are particularly useful in fields enclosed by trees or other obstacles.

Custom spraying and dusting, especially if airborne, have proved useful, providing trained operators and efficient equipment that many growers cannot afford. This service is sometimes set up as a cooperative.

Cautions. 1. Many spray materials are poison to animals and human beings. Read and observe instructions with care. Label the containers clearly, and have a regular place to keep them—an enclosed cupboard or room. Keep it locked if there are children around. Get things out only when needed, and after use put them away at once. A very little bichloride of mercury or corrosive sublimate is fatal.

2. Copper sulfate and bichloride of mercury corrode metals. Keep them in wood, earthenware, or glass. Observe directions with other substances.

3. Do not inhale sprays, dusts, or fumes unnecessarily, and avoid body contact. Use masks and protective clothing as instructed.

4. In communities where considerable use is made of pesticides, see that at least one doctor is well informed in such matters.

Economic side. Control of insects and diseases may cost practically nothing if it can be achieved by preventive measures such as rotation, resistant strains, and clean seed. It may be a large item of cost, as with potatoes, where several treatments are necessary. It may happen that the impossibility or the high cost of control may prevent the culture of a crop.

KINDS OF DAMAGE BY ENEMIES

The forms of damage by diseases and insects are several:

1. **Actual destruction** of crops and products, including those rendered unsalable by partial destruction. A crop of cucumbers attacked by bacterial wilt which was carried by insects may have to be plowed under before a fruit is picked. A tomato punctured by the tomato worm is unsalable unless the opening is dry and well healed.

2. **Blemishes on goods** reduce the price and the return. Wireworm injury in potatoes and maggot injury in carrots are illustrations.

3. **The quality of products** is impaired by damage to the plant which prevents its functioning normally. A leaf disease may so damage the foliage of a muskmelon plant that photosynthesis is checked and the sugar necessary for a sweet melon is not manufactured.

4. **Insects are frequently carriers of diseases,** especially those of bacterial and virus nature. Mosaic of peas, yellows of spinach, and wilt of cucurbits are carried in this way.

5. **The presence of insects** renders the vegetables unpopular with consumers, as witness ear worms in sweet corn, aphids on lettuce or spinach, and maggots in radish.

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14

Storage of Vegetables

In a given area vegetables mature only in their respective seasons, but people eat them every week of the year. Good nutritional standards require a constant supply.

The principal means of spreading the supply of vegetables through the year are:

1. Good timing of crops in the home garden or on the vegetable farm.
2. Transportation. See Chapter 4.
3. Processing, including canning, freezing, drying, and pickling. See Chapter 1.
4. Storage.

General requirements for storage

In all storage the principal general requirements are:

1. Low uniform temperature; for most vegetables, just over 32° F.
2. High humidity, with a few exceptions.
3. Sound, disease-free produce of proper maturity.
4. A place that is:

   (*a*) Well drained.
   (*b*) Clean.
   (*c*) Vermin proof.
   (*d*) Accessible.
   (*e*) Durable.
   (*f*) Cheap.

Storage facilities and methods fall into two groups: (1) common or unrefrigerated storage; (2) cold or refrigerated storage.

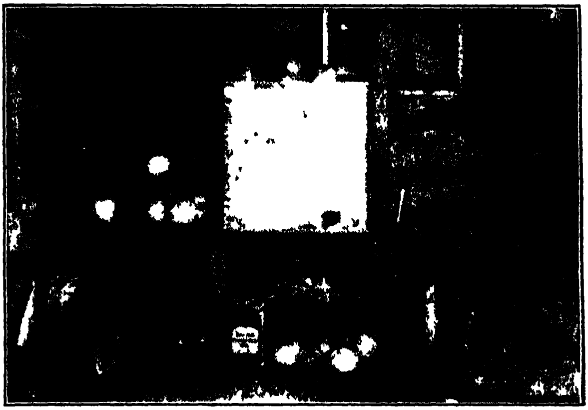
Common storage provides space, insulation against heat movement, and usually ventilation. Cold storage adds facilities for refrigeration or artificial cooling.

HOME STORAGE

Storage of vegetables at home extends the advantages of the home garden by 2 to 6 extra months. Home storage is usually

of the common or unrefrigerated type; it is feasible, cheap, and satisfactory in most of the United States. Where winter weather is too warm for the storing of vegetables, the products of the winter garden itself are available.

The development of home-refrigerated units of considerable size has brought domestic freezing and cold storage into common



Cornell University

FIG 14 1. Cellar storage, if conditions are favorable, is excellent to carry the home vegetable supply into the winter Note the window for ventilation, shelves for squash which should be kept relatively dry, and a bin (lower right) with soil for celery and Chinese cabbage Roots are buried in earth in center bin Bags of moist leaves over roots prevent evaporation.

use. Comparative costs need to be appraised with some care, including depreciation as well as operation.

Conditions for home storage

The temperature of the storage place for most vegetables should be just above 32° F. Though vegetables do not freeze until a temperature of about 30° F. is reached, some allowance must be made for fluctuations and for variations in different parts of the space. The temperature 5 feet from the floor may be 31° F., but potatoes might freeze at the floor. As temperature rises, the rate of deterioration increases (see page 265). It is hardly worth while to attempt storage of most vegetables for any long period unless the temperature can be kept below 55° F. Sweet potatoes and winter squash keep well at 50° to 55° F.

Control of temperature in common storage is largely by choice of a suitable place which is cool and naturally or artificially insulated against heat movement. Insulation safeguards against loss of heat and freezing and against entrance of heat. In the northern winter the earth is warmer than the air, and soil does not often freeze deeper than 3 or 4 feet. With outdoor weather below freezing, there is gradual movement of heat from the earth to any below-surface storage place.

Ventilators afford opportunity for warm air or cold air to flow in or out as required. Thus in the fall they would be open on cold nights and closed on warm days. In the winter, when night temperatures are low and there is danger of freezing, warm air may be admitted from outdoors on a sunny day or from the warm part of a cellar.

At times a little heat may be required to prevent freezing. An electric-light bulb, a toaster, a lantern, or a small kerosene stove is likely to serve well for a small home storage space.

Control of humidity. For most vegetables the atmosphere should be near the saturation point to prevent evaporation from the vegetables and their shrinking and shriveling. For this reason a naturally moist place is good, a pit or cave, or an underground cellar. For potatoes and cabbage there should not be free moisture on the walls or vegetables. Some vegetables such as beets and carrots are more tolerant of moisture. High temperature favors evaporation from the produce, and subsequent cooling results in condensation. Thus alternations of high and low temperatures result in disastrous drying and shriveling of the produce.

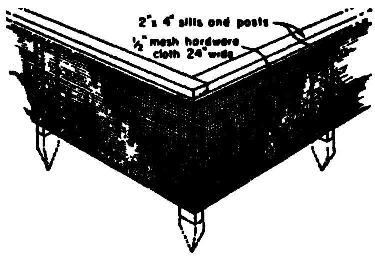
Humidity may be maintained in storage rooms by exposing pans of water or by sprinkling floors and walls. A good plan is to keep produce in a tight container, such as a barrel, oil drum, or large crock, covered with a bag of moist leaves.

Kinds of storage places

Cellars of houses, barns, and other buildings can often be adapted for home and even commercial storage without the necessity for new building. If the floor is of soil, leave it so, to favor a moist atmosphere.

It is often necessary to build a partition and perhaps to insulate exposed outside or interior walls. A single wall of building

board or of boards with building paper may serve. Walls with open air space are no longer approved, as air circulates freely within and rats love them. It is better to make a double thick-



Cornell University

Fig. 14.2. Rat guard of hardware cloth, sunk in ground outside or inside a wall.

ness of boards with paper between. If this is not sufficient, make a double wall, filling it with dry cinders or shavings. See Fig. 14.9 The wall must be kept dry. A cupful of hydrated lime to each bushel of shavings will keep rodents out. The room should have a ventilation opening, readily regulated, and a suitable door. Such a cellar is satisfactory for canned goods as well as for vegetables and apples.

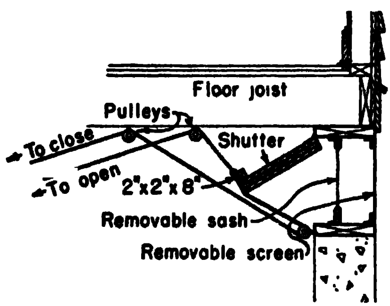


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Fig. 14.3. Detail of a good ventilator for a storage cellar.

Vermin can be kept out by sinking woven wire or hardware cloth into the ground a foot or two deep just inside or outside the wall. See Fig. 14.2.

Bank storage. Excellent results are to be had from bank, cave, or underground storage. In southern climates a bank is likely to keep cool better than a cellar, and in the north it is

immune from freezing if properly constructed Such a storage may consist merely of a barrel or steel drum set in a bank, the

Cornell University

FIG 14 4 A buried barrel keeps vegetables well These vegetables were kept in good condition from October to April

end covered with cleated boards or with the framed end of a packing box, and banked with manure or straw The one illustrated in Fig 14 4 yielded vegetables in excellent condition when students were making gardens in April, and some of the produce had actually gained in weight by absorbing moisture

A larger cave may be made by digging a space, building a crude wooden structure of old lumber or even of poles and cov-

Alabama Experiment Station

FIG 14 5 Outdoor cellar storage is efficient and convenient where good house storage is not available

ering it again with earth. If there is danger of seepage from above, the roof should be of old galvanized-iron roofing or siding. Such a structure will not be permanent but will last several years. It is unwise to make a large roof of this sort with very heavy covering or to tunnel into a bank as a cave-in may result.

For greater permanence a concrete cave may be made at very moderate cost. College bulletins and pamphlets of the Portland Cement Association (offices in leading cities) give good directions. This is a fine project for vocational work.

Pit storage. A simple, cheap, and effective form of storing vegetables is to bury them in a pit or trench, although the means of control for temperature and humidity are crude and rodents may be very destructive.

A simple procedure is to select a well-drained place, dig a trench 3 to 5 feet wide, a foot deep, and as long as necessary. This is merely to furnish soil for covering. In a poorly drained place, the pit may be made above ground. The pit is lined with straw or leaves. Vegetables, loose or in crates, are arranged in a pile. Two or three assorted lots may be put in to be taken out at different times, after which the end of the mound is again closed. Straw or leaves are added, then soil to prevent blowing away of the cover. When the weather gets cold more straw, leaves, cornstalks, or manure are added. The soil cover should not be too thick as it may freeze, and then digging it open is a hard job. Where heavy rains are probable, a strip of roofing paper may be useful to shed water.

Refer to the chapters on the various vegetables for their special storage requirements and management.

STORAGE OF VEGETABLES FOR MARKET

The object in storing vegetables for later sale is to have produce to market at times when the supply is low and prices are high.

Refrigerated storage may be provided by central commercial plants or in smaller establishments on the farm. Shipping-point dealers in cabbage, potatoes, and onions often own and manage common storage facilities. Wholesale and retail dealers at consuming centers often have refrigerated storage. Growers of vege-

tables, especially those serving roadside stands or local stores, find storage facilities both convenient and profitable.

To store or not to store

The owner of produce considering the question whether to store or not must deal with a number of factors.

The probability of increased price must be weighed with care. In general it is safe to say that the average results of storage of vegetables are not profitable. The increased returns from selling after storage over selling from the field are often not sufficient to cover costs and losses. At the same time, under certain conditions and with shrewd and careful management, storage pays.

Long-time storage of vegetables is much less common than formerly because so many outdoor areas are available to furnish a supply practically the year around. To be successful one must manage the enterprise to keep costs and losses at a low level and he must gauge his buying and selling carefully in respect to time and prices.

Holding trade. Storage enables an owner to supply his trade steadily through a longer period than if he sells from the field and so to keep his patronage.

Temporary storage is of material advantage in furnishing a steadying reservoir for harvesting and selling. Orders may be filled from storage without delay; a supply is available for Monday market without the necessity for Sunday work; rainy-day harvesting may be avoided; and short periods of excess supply may be tided over, avoiding in some degree sacrifice of prices on a glutted market. For these reasons a good number of vegetable growers have cold-storage facilities on the farm.

The costs of storage include:

1. *Labor.* Extra handling and hauling in and out of storage, extra sorting and trimming, and the care of the storage place.

2. *Equipment.* Interest, depreciation, and operation.

3. *Loss or shrinkage* traceable to evaporation, decay, respiration, and other physiological changes, and to sprouting or growth. Shrinkage of cabbage may run from 15 to 25%; onions, about 15%; potatoes, 4 to 10%, and sweet potatoes, 12 to 16%.

FIG. 14.6. Insulated concrete underground storage of a commercial grower for local market. Note the ventilators. Packing house and package storage are in the background.

Andrew Rosbough, Ohio

FIG. 14.7. Interior of a grower's cold storage, holding snap beans for a few days. Note the pallets or platforms to save labor in handling.

Common storage

Common or unrefrigerated storage of vegetables for market may be in several kinds of places: (1) insulated storehouses; (2) cellars and banks; (3) pits and mounds.

The points brought out above for keeping vegetables at home apply on a larger scale to storage for market.

Refrigerated storage

Refrigerated storage facilities range from small rooms of a few hundred cubic feet capacity for a small roadside stand up

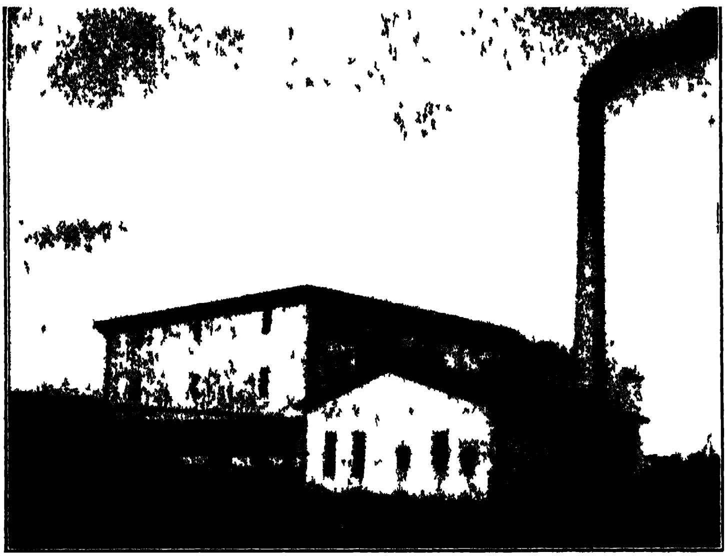


FIG 148 Commercial country cold-storage plant

to huge buildings owned by cooperatives or corporations. A market gardener may have from 1,000 to 25,000 cubic feet of space, and many country commercial refrigerated storage plants run over a million cubic feet

The advice of agricultural engineers of the colleges and of good commercial concerns in the fields of insulation and refrigeration should be used in planning cold-storage facilities.

PRINCIPLES OF STORAGE

To insure desirable results from the storage of vegetables, four sets of conditions are to be controlled, besides provision of space for the goods:

1. Temperature.
2. Humidity.
3. Composition of atmosphere.
4. Quality of produce.

Temperature

Review the discussion of temperature on page 62.

Heat is a form of energy representing molecular activity or motion. The intensity of this activity is measured as temperature; the quantity of heat energy present as heat units, B.t.u.'s or calories. One B.t.u. is the quantity of heat required to raise the temperature of a pound of water 1° F.; the calorie is the corresponding metric measure for 1 kilogram and 1° C. The small calorie, based on a gram rather than a kilogram, is used in discussing nutritional energy values. Look up thermal relations of change of state and forms of heat movement in a textbook of physics.

In storage, vegetables may be injured by low temperature, usually as freezing. At higher temperatures the tissues deteriorate through respiration and other chemical changes; harmful fungi and bacteria may develop, and the produce itself may grow. Most of these processes are speeded up as temperature rises, roughly following the law of van't Hoff (page 62), although some fungi and bacteria thrive at low temperature. A rising temperature increases the vapor pressure of liquids and so increases the rate of evaporation. It also profoundly influences the capacity of air for holding water vapor. Hence alternation of temperature in a storage place results in increased evaporation at higher temperatures followed by condensation at a lower level, which speedily robs the vegetables of water, leaving them in a shriveled and unmarketable condition.

Temperature and deterioration. Platenius (Chapter 4, ref. 5) has made a penetrating study of temperature relations involved in the deterioration of vegetables stored at various levels, observing the decline of quality as expressed in appearance, index of salability, and chemical changes. The temperature of vege-

tables after equilibrium has been reached is likely to be higher than that of the room, owing to the heat developed by respiration which continues in the harvested products.

Platenius found Q_{10} (see page 97) values to vary widely, illustrating the complexity of the factors influencing changes in living material. One of these factors is the *law of mass action,* which states that the rate of a chemical reaction varies with the concentration of the reacting materials. Thus, as the material available for respiration becomes less concentrated the rate is slowed. Also increasing concentration of certain products or by-products may slow the rates of reactions or even become toxic and lethal (killing). His graphs demonstrate that storage is not successful for any long period unless the temperature is below 55° F. but that storage time may be lengthened markedly as temperature is lowered from that point.

Platenius says, "Holding vegetables at a temperature of 35° F. for a few days to several weeks had no noticeable effect on the subsequent *rate* of breakdown when these vegetables were later transferred to higher temperatures." This is distinctly contrary to the common belief that produce goes down speedily when removed from cold storage. It must be remembered, however, that deterioration has progressed in storage, even if slowly, so that such goods cannot be kept at, say, 80° F. as long as freshly harvested goods.

Moisture

Evaporation is one of the most serious forms of quality decline in storage, resulting in loss of weight, deterioration of texture, shriveling, and wrinkling. The rate of evaporation depends upon temperature, and its extent depends upon the relative humidity of the atmosphere.

Relative humidity * is expressed as a percentage of saturation of the atmosphere.

Most vegetables are best stored at high humidity; onions, sweet potatoes, and squash are exceptions.

* Relative humidity is measured accurately by means of wet- and dry-bulb thermometers, best in the form of a *sling psychrometer* (moisture meter). Two thermometers are mounted on a bar, one with a wet cloth over the bulb. The instrument has a handle at one end by which it is whirled in the air. Temperatures are read and relative humidity deter-

Composition of the atmosphere

The atmosphere consists principally of nitrogen, 78%; oxygen, 21%; carbon dioxide, 0.03%.

Nitrogen is relatively inert, but oxygen enters actively into the process of respiration (page 96), and carbon dioxide is one of its products. If oxygen is not present in the storage atmosphere in sufficient concentration, intermolecular or anaerobic respiration occurs, usually resulting in off-flavors. This means that the oxygen is derived from changes in materials within the stored vegetables and not from the atmosphere.

Suboxidation. Many people assume that too great a concentration of carbon dioxide is injurious to stored goods, but any harm that ensues is likely to be traceable to shortage of oxygen, or suboxidation, rather than to excess of carbon dioxide. Smudge spots on cabbage, red heart of lettuce, and pitting of potatoes have been attributed to this cause.

Effect on acidity. Carbon dioxide dissolves readily in water, forming carbonic acid, H_2CO_3, a mild acid but influencing the reaction of cell sap and so affecting imbibition and permeability. In general it renders expressed sap more acid, leaving tissue more alkaline. It seems to affect the rate of respiration, upward in some cases, downward in others.

Controlled atmosphere storage, with reduction of oxygen or with ethylene or other gases, has been very effective in prolonging the keeping of apples. These methods have not thus far been used extensively with vegetables.

Quality of produce

Vegetables to be stored must be free from mechanical, insect, and disease injury, and should be at the proper stage of maturity. Most vegetables should be fully matured, but celery and cabbage keep better if somewhat on the green side. Losses are heavy enough with perfect goods; storage of bruised, damaged, or diseased vegetables is almost sure to be disastrous.

mined from a table. The difference in reading of the two thermometers is due to the fact that one is cooled by the evaporation of water whereas the other is not. The drier the atmosphere, the greater the difference.

Relative humidity is measured less accurately by means of a hair hygrometer. The hair contracts in a moist atmosphere and so moves a hand on a dial. Good electrical devices for measuring humidity are now available.

MEANS FOR STORAGE CONTROL

We have just discussed four conditions to be controlled in storage.

Seven principal means are available for the control of these storage conditions:

1. Insulation
2. Refrigeration.
3. Heat
4. Ventilation.
5. Humidity control.
6. Atmosphere control.
7. Stowage.

Insulation

Insulation [6] against heat movement is not to be confused with electrical or other insulation Substances differ in their conductance of heat. Those of low thermal conductivity, that is, those that retard movement of heat in either direction, are used for insulation. Table 14.1 gives values for the thermal conductivity of a number of materials.

TABLE 14.1. THERMAL OR HEAT CONDUCTIVITY OF MATERIALS

In B.t.u. per hour, per square foot, per inch of thickness, per 1° F. difference in temperature between the two sides. From *Cornell Sta. Bul.* 724.

Still air	0 17	Water	4.0
Rockwool *	0.26–0.29	Glass	4.6
Regranulated cork	0.30	Plaster	2.0–5.0
Cork board	0.25–0.34	Brick	3.0–6.0
Celotex *	0.34	Limestone	4.0–9.0
Shavings, dry	0.41	Concrete	6.0–9.0
Wood	0.3–1.0	Iron	400
Cinder concrete	2.0 3.0		

Aluminum foil utilizes the principle of reflection. Five sheets with 6 ¾-inch spaces conducts 0.077 B t.u./hr./sq. ft./1° difference in temperature, about equal to cork board.

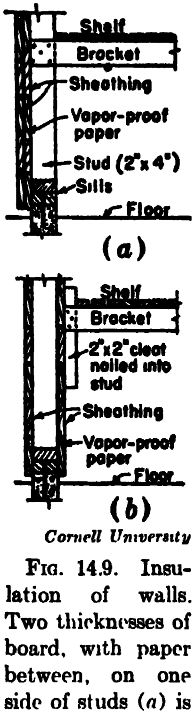
* Rockwool is a rock material fused and blown into threadlike particles. Celotex is a building board made of spent sugar cane.

Air has the lowest conductivity of any ordinary substance, and most insulating materials are effective because they are fibrous or cellular in structure and so imprison air. If air spaces are large, convection occurs and insulation value is largely reduced.

A desirable insulating material should be: (1) low in conductivity of heat; (2) good as structural material, easily applied; (3) moisture proof; (4) durable, non-decomposing, fireproof; (5) vermin proof; (6) odorless; and (7) economical to buy, install, and maintain.

Cork board is the most common insulating material for permanent storage structures; asbestos and mineral wool are also used. Shavings and cinders are cheap but have disadvantages.

Masonry and concrete walls are only one-tenth as good insulators as cork board, but they are usually thick and may be lined with other non-conducting material. Two or three feet of earth over a concrete roof is effective, and such movable materials as cornstalks, straw, coarse manure, or leaves are all useful. They are more effective if dry.



Cornell University

Fig. 14.9. Insulation of walls. Two thicknesses of board, with paper between, on one side of studs (*a*) is considered as effective as (*b*), which provides air space. This construction is good if the space is filled with a suitable material.

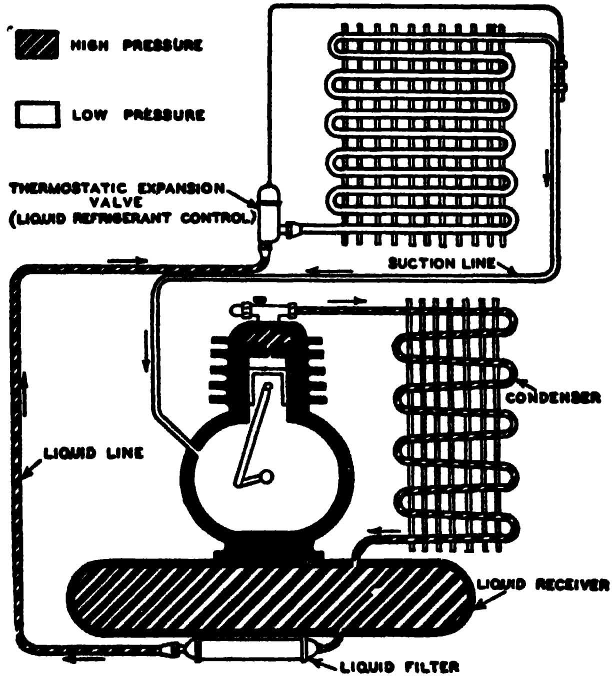
Refrigeration

Refrigeration[6] includes various artificial means for removal or disposal of heat. All practical methods involve the heat relations of change of state. Ice cools its surroundings because each pound in melting takes up 144 B.t.u. of heat. Cooling by dry ice or solid carbon dioxide involves both melting and vaporization; although its temperature is −114° F., dry ice is only about twice as effective a cooling agent as water ice.

Mechanical refrigeration makes use of a compressor which draws the *refrigerant* in gaseous form from the pipes or cooling unit of the refrigerated space, compresses it, and passes it on to a cooling unit where it is condensed or liquefied. See Fig. 14.10. A current of cooling water around the pipes carries off the heat. The cooled liquid refrigerant next passes through a valve, usually automatically controlled, into the pipes of the room or cooler unit which constitute the heat-absorbing system. Here the heat of the chilled room and of the produce in it boils the refrigerant,

which then completes the cycle and passes on to the compressor again.

In many newer installations the heat-absorbing system consists of a cabinet containing many small finned pipes of a metal



General Electric Company

Fig. 14 10 Compressor refrigeration system Ammonia is a common refrigerant Liquid gas is released from pressure at the expansion valve, boils in the coils which are in the storage chamber, and so takes up heat and cools the room Gas passes to compressor, then to condenser at high pressure, giving up heat and being liquefied, thence to the receiver and to the expansion valve, so completing the cycle. High-pressure side is shaded; low-pressure is white Other refrigerants work by the same principle.

of high conductivity such as aluminum, with a fan to aid in the circulation of the air. Such a system may be adapted for humidity control.

The commonest material used for a refrigerant is ammonia, NH_3. This boils at 28° F. and has a heat of vaporization of

589 B.t.u. A number of other refrigerants, notably "Freon-12," are used, especially in smaller installations.

A refrigerating plant is rated in tons, 1 ton representing the capacity to dispose of the same quantity of heat as is involved in the melting of a ton of ice, or 288,000 B.t.u., in 24 hours. This is roughly equivalent to making a ton of ice.

Heaters

A small furnace, a stove, or even an oil drum may be needed to maintain a desired temperature, to prevent freezing, or to cure sweet potatoes. Oil heaters designed especially for temporary use are available.

Ventilation and air circulation

Ventilation is an important means of modifying temperature in common or unrefrigerated storage. See page 265. Circulation of air is also important to insure uniformity of temperature throughout the storage space. Gravitation partially takes care of this, since warm air is lighter than cold and tends to rise. Fans are usually part of a cooling unit or are installed separately. It is often necessary to provide raised floors, spaces between produce and walls, and between bins or stacks of crates.

Ventilation to change the air is of little value; in fact, as pointed out above, reduced oxygen and increased carbon dioxide may be beneficial.

Humidifiers and driers

For most vegetables high humidity is necessary to prevent shriveling and loss of weight and quality. When a cold-storage room is practically full of produce, the air soon becomes saturated or nearly so. Some of the evaporated moisture is condensed as frost on refrigeration pipes. Keeping a minimum differential between the temperature of the pipes and that of the air holds this frosting to a minimum. Cabinet coolers or blower units are desirable as taking less moisture from the air if humidity is high, and they are easily fitted with spray equipment to increase the humidity of the atmosphere. On a small scale, exposing open water and sprinkling may be resorted to for maintenance of humidity. Trays of calcium chloride may

be used to remove moisture from air. Air-drying equipment is also available.

When reduction of oxygen and increase of carbon dioxide in storage atmosphere are undertaken it is necessary to make walls not only air tight but also gas tight.

Stowage

Good storage requires that produce be stowed in good shape. Cabbage, usually stored in deep, narrow bins, is best laid in orderly fashion to minimize settling. Squash are laid only a few layers deep. Celery, root crops, and onions in crates are stacked with space between for air circulation. Boards or 2 by 2's are laid between layers or alternate layers to make the stacks secure and to provide for circulation. Large crates and pallets are sometimes used with lift trucks to save labor.

STORAGE STRUCTURES

Refrigerated storage buildings may be constructed of wood, masonry, or concrete, with appropriate insulation. Old buildings may be remodeled and adapted and insulated, but it is worth while to be sure that they are suitable.

In any structure where the load is not carried on the ground, collapse must be guarded against.

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15

Exhibition of Vegetables

People learn readily by seeing, by visual instruction. They are interested in and inspired by competition and high achievement. These two striking characteristics of human beings make exhibition a most useful method of education, not only for students but no less for the general public, for the participants, and for spectators.

Some of the smaller school and community exhibitions are setting an example to county fairs, many of which are in a bad way through commercialism, questionable amusements, and neglect of agriculture.

The National Junior Vegetable and Potato Growers Association, Future Farmers, and 4-H Clubs have done excellent work in promoting exhibitions, training in judging, and demonstration.

The object of a vegetable show is to advance education by assembling and displaying the finest products of the gardener's art and to grant recognition for high achievement in that art. A vegetable show is also valuable because it leads people to think about vegetables, about their points of excellence and their defects. It affords excellent promotion for the sale and use of good food. It gives opportunity for gardeners, home or commercial, to meet, compare notes, and consult with specialists.

The vegetable show makes a real contribution from the consumer's standpoint, helping to establish high standards of quality, which means not only good food and economy for the buyer but also encouragement for the good commercial grower.

The scope of a show. The vegetable show should be much broader than a mere display of fine specimens, singly or grouped. It may be concerned with good packaging and good marketing as well as good production. Competition and instruction in identifying and judging vegetables are often included. Contests in growing crops from seedtime to harvest may find their climax

in competitive showing of the products at the autumn exhibition. Classes may be included for home or commercial gardeners of the community. Interest in and usefulness of the show may be increased by admitting commercial exhibits of local merchants, showing seeds, plants, equipment, and supplies.

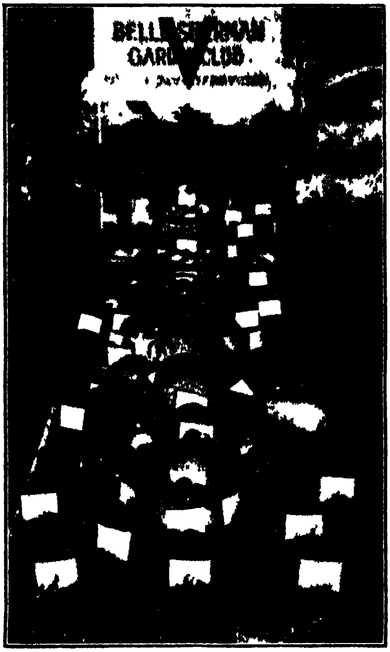


FIG. 151 County fair exhibit from a community garden project.

The suggestions of this chapter are centered around the vegetable show, but they may be applied in connection with a horticultural show or a general school fair. Of course they are subject to wide adjustment to fit individual circumstances.

PRECAUTIONS

While advantage is taken of the values of the exhibition project, care must be exercised to avoid its pitfalls.

Sportsmanship and integrity. The quest for excellence must be pursued in the spirit of fine sportsmanship and in strict honesty. Modesty adorns the winner, and generous recognition

of the achievement of others is graceful in the loser. Many a fair is blemished by the quest for dollars, by showing products that have been grown by others or by other violations of rules, and by favoritism on the part of officers and even occasionally of judges. A show may better be omitted than to let it be the occasion for training in trickery and misrepresentation.

Simplicity. Danger lies in making the whole plan and set-up too elaborate. Do not try too much, especially the first time. A small number of classes, well spaced and well handled, leaves a better feeling after the show than if too much was attempted.

Special caution is needed with respect to expenditures of money. The greater the cash obligations that are incurred, the harder it is to meet them and the greater the danger of deficits and hard feelings. If a show can be put over without an admission charge, it is well. Needless to say, the money affairs must be kept strictly in order so that all is accounted for in detail. Achievement of success in matters of this sort is the finest sort of experience. It is better to wind up a dollar ahead than a dollar behind.

PLANNING A SHOW

Following is an outline of the steps to be considered in planning a vegetable show:

1. **Decide whether to hold a vegetable show or not.** Consider the advantages and the obstacles thoroughly.

If the answer is yes, arrange for a general or executive committee to take charge. The first job will be to decide what the show is to accomplish, what is to be included, and who may exhibit.

2. **List the various jobs or groups of jobs.** The general chairman should not undertake too much detail. A good scheme is for each other member of the general committee to head a subcommittee for a special task. Plans should include: (*a*) general management and finance; (*b*) place and staging of the show; (*c*) premium list, entries, judging, and awards; and (*d*) publicity and attendance.

These jobs may well be subdivided as seems best, enlisting the help of many, but holding each person responsible for his clearly defined share of the whole task. For school fairs, adult counse-

lors may be enlisted among teachers, parents, and others interested Reaching outside the school helps to develop community interest and support The chamber of commerce, service clubs

Photograph by Hess courtesy Stumpp & Walter

FIG 15 2 Estate garden display in the English style

such as Rotary and Kiwanis, and garden clubs are often glad to sponsor a show

3 **Choose the time and place.** Choice of dates should take into account the season when most vegetables will be in good shape to show, the availability of a suitable place, and conflict with other events The place should be conveniently located for those who stage the show, for exhibitors, and for attendance.

FIG 15 3 Competition among associations in plates and market packages

The school gymnasium, an armory, a dance hall or rink, a county fair building, a grange or lodge hall, or a big barn floor may be suitable. If no other place is available, a tent may be rented for main or supplementary space.

The place should (*a*) afford adequate space, (*b*) be well lighted, and (*c*) be easily kept clean. Entrances and exits should be ample and safe.

Decorations should be simple and in keeping with the show. Flowers are more appropriate than bunting, and the vegetables should be allowed to tell their own story.

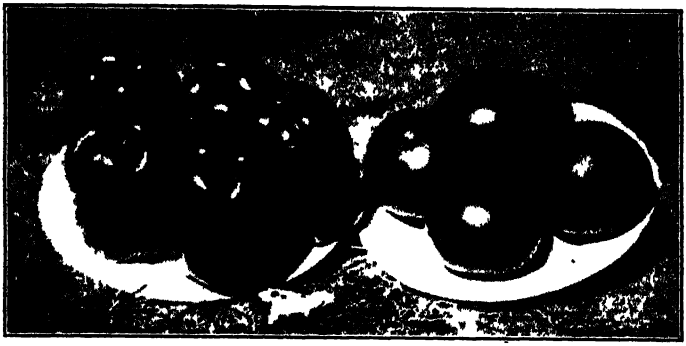


FIG. 15.4. Fine plates of peppers and tomatoes shown by 4-H boys The young people are showing the adults how to exhibit vegetables.

4. **Prepare a premium list and rules.** Procure premium lists from several fairs and shows, and look up bulletins on exhibition. Ordinarily you will not follow any one book, but you will find suggestions in many that will help you to build a suitable plan. In writing the premium list and rules, be very specific so that as many as possible of the questions that are bound to arise will be answered.

Having decided on the general plan of the show, lay out the classes in each division. It is best to keep the list short, especially for the first year, doing things well and avoiding overcrowding of space, which wrecks the effectiveness of any show.

The group award system as developed by Dr. A. J. Pratt of New York is being increasingly used. This plan does not limit the judges to the award of a single first and a single second premium. If two or more excellent entries are so close that it is hard to decide between them, all receive blue ribbons, and red ribbons go to entries that are good but clearly secondary in excellence. If necessary, yellow, green, and white ribbons follow. Prize money is pooled and divided proportionately. Some good school shows have only ribbon prizes.

The group award system encourages wide participation, but precautions should be taken to discourage showing of unworthy produce.

Money awards are best kept small, merely to compensate for some of the cost and trouble of preparing material for exhibit. The main incentive should be achievement, not the value of the prizes. Merchants and manufacturers are often glad to contribute cups or goods for premiums. A good useful article of permanent value, a camera, a desk lamp, or the like, is better than a cup or plaque. Solicitation for prizes should be without pressure, offering opportunity for voluntary aid and avoiding any impression of a "hold-up."

5. **Give the show adequate publicity.** Begin early, planning announcements in sequence so that interest will be built to a climax at the time of the show. An English class may well do the writing, which should be very different from conventional "compositions." Younger classes will enjoy making posters with color work of their own or with clippings from seed catalogues or other sources. Local papers are usually glad to cooperate. Announcements may well be carried home by pupils. Merchants may be asked to make special window displays of vegetables, helping the show and using the show to help their own sales. Publicity during and after the show, including recognition of awards, names of judges, and other interesting news, should not be overlooked.

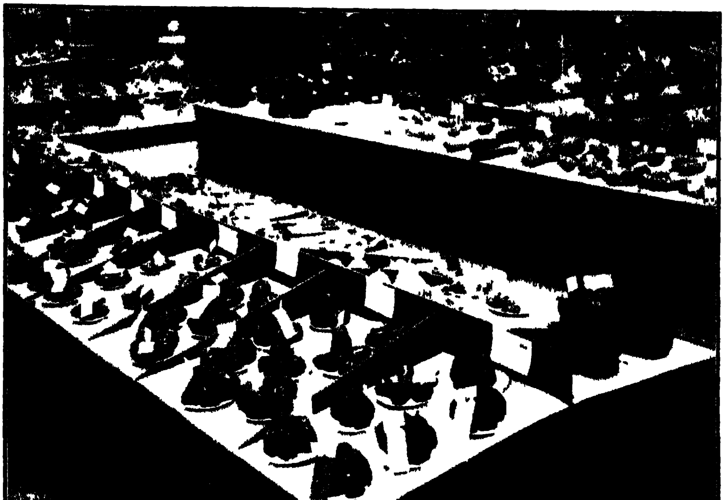
6. **Stage the show attractively and effectively.** The interest and educational value of a show depend in large degree upon orderly arrangement and upon full and clear labeling. Crowding detracts both from the appearance and from the usefulness of an exhibit.

Tables of some sort are necessary. Dining tables from a church or grange or lodge may be available. Boards laid on horses or trestles or even on orange boxes will serve. If they are rough or unfinished, cover them with paper from a big roll. Orange boxes are good for shelves and banking of displays.

Instead of paper, moist peat moss is used in some exhibits as a ground for displays. Some vegetables are well displayed on paper plates, others laid on the tables.

There should be ample signs to tell what the various classes are, for visitors seldom study premium lists. Classes may be

separated on the tables by tape, binder twine, or chalk marks. Class labels may be held upright by thumb-tacking to little



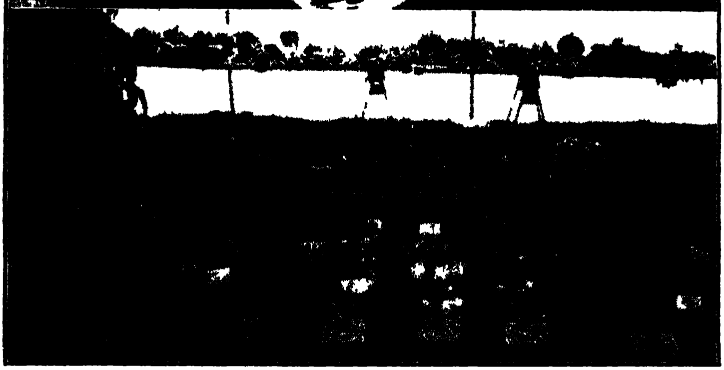


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FIG. 15.5. (*Top*) Well-labeled classes at a state fair Sloping tables properly covered, with classes clearly divided, all contribute to educational usefulness as well as to appearance.

FIG. 15.6. (*Bottom*) Same ideas carried out less formally at a county fair and at low cost in time and money.

triangular blocks of wood. A student who has had experience in lettering can usually be found, or a typewriter may be used.

7. **Establish a clear-cut and definite system of entries and records.** Much confusion and even hard feeling is avoided in

this way. In large shows advance entries help in planning for space and in preparation of records. In smaller shows this is not necessary, adding only to complication. If entries are required, the fact must be well announced or some good exhibitors will be barred. After entries are in, the secretary in charge makes up a book showing just what exhibitors have entered in each class and providing space for record of awards. In larger fairs exhibitors are sometimes assigned numbers for convenience and in order that their identity may not be known to the judges. This is seldom done in school fairs; the group award or merit system has made less need for it. When awards have been made, the secretary must see that prizes are delivered.

8. **Get a good judge,** and give him a fair chance at the job. A judge should know his varieties and the standards of excellence, should have broad gardening experience, and should be able to explain decisions and assist exhibitors If possible, a clerk should accompany the judge to place ribbons and to record awards in the entry book. It is well to use a paper stapler to fasten the ribbon to the entry or name tag. Naturally, the utmost care must be exercised to avoid errors and misplacing of tags and ribbons. Among persons available for judging are the specialists from the state college, the county agricultural agent, teachers from other schools, and growers or home gardeners who have had experience in judging.

9. **Wind the job up fully and smoothly.** After the show is over, everybody is tired. Nevertheless, it is necessary to see that the enterprise is finished off to a clean conclusion. Records must be completed and press stories given to reporters or mailed to the newspapers. Equipment must be returned to its proper owners and places. The hall must be cleaned up and everything left in good order. All this contributes to the satisfaction of the committees in the feeling of a good job well done, and it leaves a favorable impression with teachers and all concerned. Then the way is clear for another and better show the next year.

JUDGING VEGETABLES IN A SHOW

One of the best ways to learn the characteristics of vegetables and to master the standards of excellence is to practice judging

as if one had the job at a show. This is an important teaching method in club and school work. A valuable guide is to be found in bulletins and in the United States Standards used in sorting and inspecting vegetables for grade (U. S. No. 1, 2, etc.).

The general standard of excellence is nowadays properly based on the value of the product to the housewife and her family rather than upon a set of arbitrary show points.

Size of specimens should be typical of the variety at best table stage. In years past too much emphasis was given to large size. Most housewives prefer medium-sized or even small specimens. There is a place for competition for the *largest* pumpkin, squash, or cabbage, as a matter of interest and fun and publicity, but this is not to be confused with competition for the *best*.

Specimens should be clean, fresh, and firm. If the show is to last even two days, samples should not be overmature, as some kinds will go down rapidly on the show table. In preparing exhibits, care must be exercised to avoid damage in washing, brushing, or handling. If exhibits are to be shipped, specimens will need to be individually wrapped and packed with care. No general rule can be laid down about temperature and moisture, but refrigeration, icing, and sprinkling may be practiced to advantage with some products.

Blemishes. Insect damage, disease blemishes, and mechanical injury are serious matters on the show table. A plate of apples must be practically free of such defects, and vegetable judges are becoming quite as strict.

Uniformity is not a character in itself, but it is a term to be used in describing character such as size or color. Thus a score card should not be made up: size, 20; shape, 30; color, 20; condition, 15; uniformity, 15. Rather the 15 points should be divided among the four characters and deduction should be made from the score for each, if uniformity is lacking in that respect.

There is bound to be difficulty and confusion between weight assigned to excellence as representing a *kind*, say as a tomato, and excellence as representing a *variety*, as Rutgers. In general it is well to judge primarily on the broad basis of the kind of vegetable but to assign some weight, say, 10 to 20 points, to trueness to varietal type. A plate of Earliana can be very true to its type but still be an inferior tomato.

DEMONSTRATIONS

A vegetable show affords fine opportunities for teaching the principles and practice of judging. The teacher or the judge may well be asked to show just how the work is done, with explanations of decisions and suggestions for better achievement in the future. Some shows provide a special place for demonstrations, with table in the middle and banked seats or bleachers all around.

PRODUCTION CONTESTS

Production contests, announced well before planting time, may be handled in many ways. They may be concerned with many vegetables in a home garden or with a single crop for market or processing. Such contests call for all-around excellence and not merely growing and showing good specimens. Possible score cards are given below:

Home Garden	
Variety and succession	20
Record and account	20
Total yield, pounds or dollar value	20
Care and skill in gardening	20
Display at show	20

Commercial Crop	
Management and care	20
Record and cost account	20
Yield, U. S. No. 1	20
Quality of product	25
Exhibit at show	15

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2. Somers, Lee A. "Vegetable exhibitions, their planning and management," *Ill. Ext. Circ.* 455, 1936.
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ANALYSIS OF CROP PROBLEMS

Our country is so wide and conditions of soil and climate are so varied that clear-cut directions for crop production can seldom be laid down with assurance. The following outline suggests the factors that should be considered for each crop, and it will guide in the various chapters.

Steps in Growing a Vegetable Crop

1. Decide whether the crop is appropriate and promising for the climate, for the soil, for the farm scheme, and for you.
2. Select the field; prepare and fertilize the soil.
3. Choose a variety, and procure good seed.
4. Plant.
5. Weed and cultivate. Resort to irrigation when it is needed and feasible.
6. Control diseases and insects.
7. Harvest.
8. Market.

In studying the various crops, make use of applicable portions of other chapters.

The following outline of the procedure for crop trouble-shooting, prepared by the junior author, appeared in "Cyanagrams," American Cyanamid Co., New York, Spring, 1953.

Consistent diagnosis depends on (*a*) subject matter information, (*b*) field experience.

A. Is it an insect, disease, or cultural problem?
   1. Insect symptoms (a hand lens is essential equipment).
      a. Presence of insects on foliage, in stems or on roots—bean beetles, corn borer, seed corn maggot.
      b. Signs of feeding (chewing or sucking)—mites, tarnished plant bug.
   2. Disease symptoms: Usually not uniform throughout the field, nor will one disease affect all crops.
      a. Dead areas on leaves or stems—black rot on cabbage, tomato blight.
      b. Vascular tissue discoloration—verticillium wilt, yellows.
      c. Virus patterns—tobacco mosaic.

3. Cultural.
   a. Nutrient deficiencies.
      (1) Yellowing—nitrogen.
      (2) Stunting—phosphorus.
      (3) Dead tissue—boron.
   b. Nutrient toxicities—usually similar to deficiencies.
      (1) Major or minor elements—boron toxicity on beans.
      (2) Soluble salt injury (usually from excessive nitrogen).
   c. Soil problems.
      (1) Drainage.
      (2) Structure.
      (3) *p*H.
   d. Pesticide injury.
      (1) Insecticide burning or stunting—DDT on vine crops.
      (2) Fungicide burning or stunting—copper on melons.
      (3) Herbicide burning or abnormal growth—2,4-D on tomatoes.
   e. Climatic.
      (1) Sunburn.
      (2) Low-temperature injury (blossom drop, catfacing).
      (3) Premature seeding.
      (4) Wind injury.
   f. Physiological—(tip burn of lettuce, blossom end rot of tomatoes, onion blast, celery blackheart).
   g. Miscellaneous—gas fumes, creosote injury, black walnut toxicity, and thousands more.

B. Look for a "pattern" to the symptoms.
   1. Correlation between low spots, high spots, nearness to hedgerows, row patterns.
   2. Correlation between farming operations, e.g., time of seeding or field planting and dry weather.

C. Record background information.
   1. Date symptoms first noticed.
   2. Field history.
   3. Fertilizer and liming practices.
   4. Check *p*H.
   5. Pest control program (insects, diseases and weeds).
   6. Rotations.
   7. Weather conditions.

Crop problems do not follow the rule book. Each situation is different. There is no substitute for experience. If you run over these points, however, the solution may come more readily.

16

Potato

The potato is the most important of all vegetables, almost as important, indeed, as all the rest of the vegetables put together. Southerners call it the white or Irish potato to distinguish it from the sweet potato. It is one of the world's great food plants, especially in Europe and America. It grows well for home use, in its proper season, almost anywhere in the United States, and commercial areas are found in all regions. The south ships potatoes north in late winter and spring, and the north ships them south in the fall and winter, for this crop will not tolerate the heat and drouth of southern summers. Its suitability for storage without refrigeration contributes greatly to its usefulness.

The Irish potato has undergone more drastic change in geography, yield, production methods, and use than any other major food crop. Present-day commercial potato production is centering more and more in areas where conditions are especially favorable for high yields. High cost of labor necessitates highly mechanized operations, with large fields and low cost per bushel.

ADAPTATION

The potato, though sensitive to frost, is a cool-season crop, a winter or spring crop in the south. It develops best at temperatures of 65° to 70° F. Cool temperature and adequate moisture are especially important at tuber-setting time, when underground stems, called stolons, grow out, each to be tipped with a tuber. Thus, the tuber is a *stem* in contrast to the sweet potato which is a *root*.

Bushnell [10] suggests that high temperature interferes with the formation and growth of tubers by favoring a rapid rate of respiration in the above-ground part of the plant, resulting in a

deficit of carbohydrate available for the growth of underground parts. Setting of too many as well as too few tubers may reduce yield.

In some states potatoes commonly suffer from inadequate rainfall. In other states a rainy season occasions serious loss from the late blight disease.

SOILS

Potatoes are planted commercially on a wide range of soils from mucks and light sands to moderately heavy soils. Crops on heavy soils are more liable to disease, and tubers are more likely to be off-type and dirty, than those grown on lighter soils. On the other hand, the heavier soils give good results if well drained and well supplied with organic matter Muckland potato culture has gained rapidly in recent years. The notion that potatoes from these soils are inferior in quality is apparently not well founded, if drainage fertility, and other cultural conditions are favorable.

Soils for potatoes should be friable, fairly deep, well drained, well aerated, and well supplied with organic matter.

Since the potato tuber grows in the ground and many features of its quality depend on the soil, land for this crop should be thoroughly prepared and fairly deep.

ROTATION

The potato in the north is usually grown in a crop rotation, often following sod. Old sod, however, is likely to harbor wireworms and grubs In truck-crop areas, formal rotations are not common. Potatoes are often grown on the same land year after year, with cover crop planted after harvest to maintain organic matter.

FERTILITY

Soil reaction for the potato should be within narrow range. The plant itself does well from about *p*H 4.8 to over 7.0, the neutrality point. At the higher or less-acid level, however, a fungus trouble, scab, becomes a serious menace. Thus a suitable range is about *p*H 4.8 to 5.4. These *p*H levels will vary

somewhat with regions and soil types. See Chapter 10 concerning changing pH of soils.

Fertilization practices are best planned in accord with local advice and experience. General recommendations applicable over a wide range of conditions are not feasible even though it is truly said that the potato is a "heavy feeder." It responds to liberal applications of manures and fertilizers. Within limits, liberal feeding is likely to reduce the cost per bushel, to improve market quality, and to increase net returns. Fifteen dollars buys 500 or 600 pounds of fertilizer, and, even at 75 cents a bushel, only 20 to 25 bushels per acre increase in yield is required to meet the cost of purchase and application. If, on the other hand, extra fertilizer will not bring results, it should not be used unless and until other conditions such as organic matter, soil reaction, quality of seed, or cultural practices are so improved as to make it profitable to apply the fertilizer.

Stable manure is good for potatoes, but it should be applied for the previous crop, especially if land is in sod. It may be applied shortly before plowing, but better practice is to apply it in time to help the preceding hay crop and to increase the quantity of organic matter to be plowed under. Manure favors scab development if put on shortly before planting.

Manure is low in phosphorus. Hence, a fertilizer of high phosphatic ratio such as a 1–3–1 or 1–2–2 is used along with manure.

Commercial fertilizers may be applied in quantities ranging from a few hundred pounds up to as much as 3,000 pounds per acre. Analysis is usually high in phosphoric acid and potash, especially in the lighter soils. In the absence of better advice a 5–10–10 analysis may be suitable, but local recommendations should be followed.

Row or band placement of fertilizer (see Chapter 10) for potatoes has proved profitable, but the material should not come in contact with seed pieces as it is likely to cause serious injury and poor come-up. Modern planters are equipped for band placement. On a small scale, a field may be marked out with a plow, and fertilizer may be applied through a pail hung on the plow with a properly adjusted hole in the bottom. It is best to use free-running fertilizer for this. A chain following the plow will mix fertilizer and soil; or fertilizer may be strewn in

the planting furrow by hand or with a wheelbarrow distributor and then mixed with a wheel hoe or horse cultivator.

VARIETIES [7]

A grower of potatoes commonly plants a single variety rather than several, usually one generally grown in the community, as adapted to climate, soil, and market.

Many new and distinct varieties of potato have been introduced during recent years. Many of them have found favor by reason of high yield, disease resistance, appearance, table quality, and other characters. Of the older ones, Cobbler, Bliss Triumph, Green Mountain, and Russet Rural are still important.

Ideal. A good potato variety should:

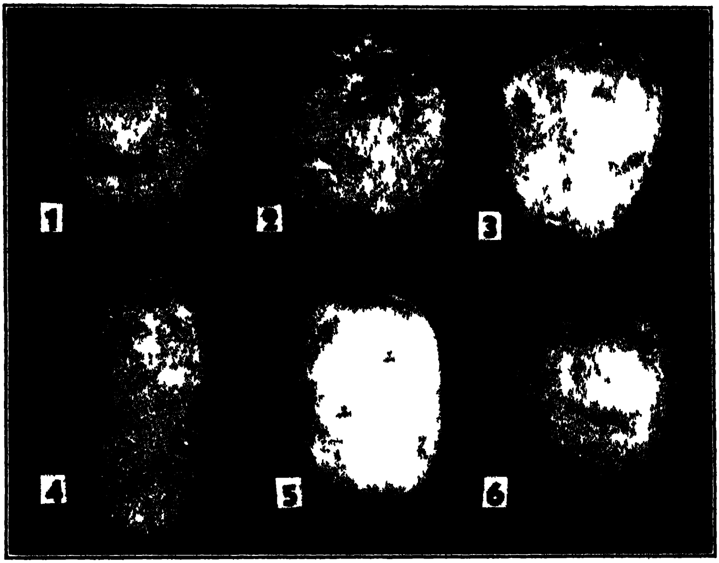
1. Be adapted to the local situation of soil and climate.
2. Be disease resistant, particularly to blight, scab, and virus.
3. Set tubers well.
4. Yield well.
5. Have tubers that are:
   (*a*) Shapely, preferably slightly elongated, slightly flattened.
   (*b*) Smooth with few and shallow eyes.
   (*c*) Preferably white, although some red and russet varieties are important.
   (*d*) Of good cooking quality, not subject to darkening. Bakers should be mealy; others intermediate between mealiness and sogginess.

William Stuart in 1915 published a classification and description of potatoes that stood the test of time even though many new varieties and strains have been developed. Clark and Lombard have published a new one.[7] What potato people call *varieties* correspond more nearly to *strains* of other vegetables, and the potato *groups* correspond more nearly to *varieties*. Even an expert cannot distinguish between certain so-called varieties, but the groups are separated by good differential characters.

Cobbler (Irish Cobbler) is a widely grown early variety, round, slightly flattened, creamy white, with sprouts slightly or distinctly tinged with violet. Eyes are deep, and tubers are often somewhat rough and angular. Vines are rather large and somewhat spreading. Widely grown for early market from the Carolinas to Canada.

Triumph (Bliss Triumph) is very early, round, red-skinned, with reddish violet sprouts Eyes are medium in number and depth Vines are small and compact, and yields are somewhat low Widely grown in Gulf, south-central, and north-central states

White Rose is a medium early variety Tubers are white long somewhat flattened tapering toward the rounded ends Eyes are fairly prominent, and sprouts are tinged with pink Vines are of medium size, stout, and rather erect This is the main variety in California



Cornell University

FIG 161 Varieties of potatoes

1 Cobbler	2 Bliss Triumph	3 Chippewa
4 Russet Burbank	5 Green Mountain	6 Russet Rural

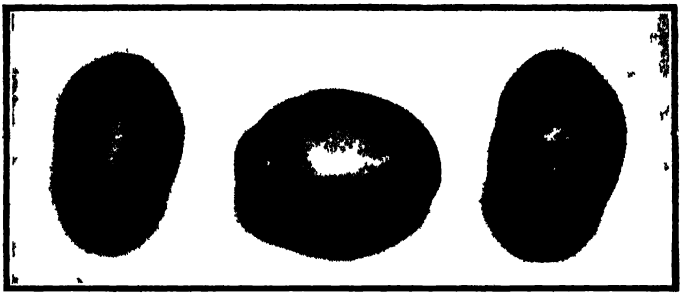
Russet Burbank is medium to late maturing shows long cylindrical tubers, only slightly flattened Skin is russet, eyes numerous and shallow, sprouts faintly tinged with pink Vines are bushy and of medium size Important in Idaho

Green Mountain is a midseason variety with oblong, flattened tubers, creamy white skin, partly netted smooth, shallow-eyed, with white sprouts Vines are large, strong, and well branched, upright at first but spreading later This is an important variety in Maine, along the Atlantic Coast, and in Michigan, Wisconsin, and Minnesota

Russet Rural. Tubers are rounder than Green Mountain, flattened, with few shallow eyes, purple sprouts, and vines that are moderately large and spreading Widely grown from upstate New York and Pennsylvania to Minnesota and in Colorado

Katahdin is midseason, heavy yielding immune to mild mosaic Vines are medium to large and spreading Tubers are roundish, smooth, and grade out very well Katahdin ranks first in certified seed production It is widely grown from Maine southward, and in the midwest

Sebago is late, somewhat resistant to scab and blight Tubers are white round-oval smooth with a medium number of shallow eyes, and with pink sprouts It is popular in the south



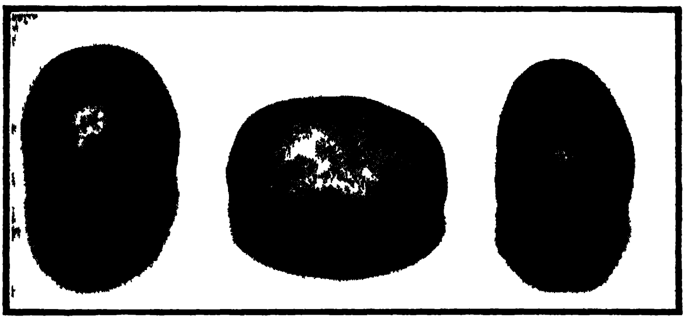


Fig 162 Varieties of potatoes Katahdin above, Kennebec below

Pontiac is a late variety red skinned round-oval, with many eyes of medium depth, and colored sprouts

Chippewa is medium early, resistant to mild mosaic, heavy yielding, with flattened oval tubers, white, smooth, and of good grade-quality

Kennebec is a little earlier than Katahdin, resistant to late blight and net necrosis Tubers are oblong-round, smooth, white, with a medium number of eyes of medium depth, and pink sprouts Starch content is high

Warba is a good early variety for home gardens

Ontario is highly resistant to scab It is late, heavy yielding, but very susceptible to black spot, smooth, of mediocre table quality

PROPAGATION

Irish potatoes are propagated by planting whole or cut tubers that have been kept in storage from a previous crop.

Certified seed. The potato is subject to a number of virus diseases—mosaic, mild mosaic, spindle tuber, leaf roll, and yellow dwarf—which greatly reduce yield and quality. The one safeguard against them is the use of disease-free seed. An elaborate system of inspection and certification has been built up so that good seed as regards type and breeding, as well as freedom from disease, is generally available. Growers of certified seed ordinarily buy well-bred planting stock or maintain their own stocks. This involves careful testing for yield and type as well as for freedom from virus diseases. Production of certified seed gained from 10,000,000 bushels in 1938 to 44,584,000 bushels in 1953. This is enough to plant all of the 1,500,000 or so acres ordinarily grown. Surplus certified seed is sometimes sold as table stock. Prices of certified seed ordinarily follow table stock prices closely at a slightly higher level, and the difference is so small that there is little occasion to use inferior planting stock.

Most potato seed stock, as planted commercially in areas south of the New York-Pennsylvania line, is grown in northern areas ranging from the Maritime Provinces of Canada to the state of Washington, where temperature conditions favor good yields and high vigor.

Storage of seed. When seed is to be stored, it is best kept at temperatures between 36° and 40° F., with an atmosphere sufficiently moist to prevent shrinking. Fluctuating temperature favors alternate evaporation from the tubers and condensation on the walls, on the roof, and on the potatoes. High temperature favors evaporation, increased loss by respiration, disease development, and sprouting. Too low a temperature, short of freezing, results in a slower start in growth and poorer stand.[8] Freezing may occur at temperatures around 29° F.

Seed treatment. If rhizoctonia or scab is present on seed potatoes, treatment of uncut tubers with formaldehyde or bichloride of mercury is recommended. Use 4 ounces of the bichloride to 30 gallons of water, soak the tubers 1½ to 2 hours,

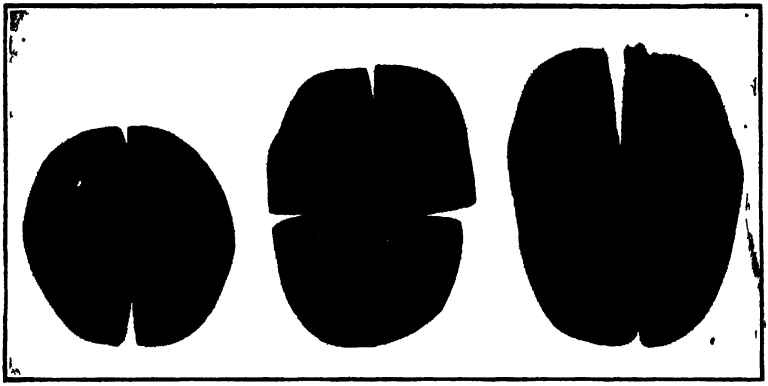


FIG. 16.3 Potato cutting

and dry. Follow recommendations of your own state as to treatment and methods.

Quantity of seed planted per acre has been increasing fairly steadily. Zavitz long ago found that yields rose when size of seed piece was increased up to 2 ounces and when as much as 40 bushels per acre was used, but seed cost renders such lavish planting uneconomical. Good practice commonly ranges from 25 to 35 bushels per acre. More liberal seeding and closer spacing are justified when other conditions as fertility, moisture, and climate are favorable for a heavy yield.

W Va Expt Sta.

FIG. 16.4. Bin for rapid seed cutting. Watch your fingers.

Size of seed piece. Increase in quantity of seed per acre is associated with size of seed pieces and spacing. Oversized pieces give many stalks per hill and a lower percentage of good potatoes. Pieces from 1¾ to 2 ounces are generally recommended.

Pieces should be "chunky," and each should show at least one good eye, which is a bud cluster capable of developing into one

or more shoots. The work of seed cutting may be speeded up by use of a bin, tubers being fed out to a shelf or table on which a knife is fixed. There are also mechanical cutters, but they cannot assure cutting so that every piece possesses a good eye.

Small, whole tubers do well and have the advantage of being less liable to decay in the ground, besides avoiding the cost of cutting. Some farmers buy the small tubers of certified seed growers for these reasons and also to save expense.

Curing of cut seed. The cut surface of the seed should dry gradually and callus over before planting. Callus refers to the formation of a layer of woody or corky cells, called wound periderm, which protects against drying before and after planting and against decay in the soil, especially if the soil is cold, wet, or infected with disease. A temperature around 65° F. is desirable along with high humidity. Seed pieces should be in slatted crates for the free circulation of air. Curing may be omitted if the soil is warm and not too wet. Cut seed heats rapidly if piled without adequate ventilation, and vitality is speedily lost.

PLANTING

Spacing. Potato rows are usually 34 to 36 inches apart, but narrower spacing is finding favor. Spacing in the row depends upon the size of the pieces, the quantity of seed per acre, and favorableness of other factors for heavy yield. The common range is 9 to 12 inches. At 9-inch spacing in rows 3 feet apart, 1½-ounce seed pieces require 33 bushels of seed per acre.

Time of planting should be gauged by three considerations: (1) desired time of maturity, (2) time of most favorable conditions for the critical tuber-setting stage, and (3) sufficient time before frost to insure a good yield even though unfavorable weather may occur.

In some sections consideration must be given to most favorable planting time to avoid certain diseases and insects. The Greeley section of Colorado plants late to avoid fusaria, flea beetles, and potato beetles. In the north, early planting is good policy. Less loss is incurred by leaving mature potatoes undug for a time than by being forced to harvest a low yield of immature tubers which are easily injured. Planting too early increases the danger of decay of seed pieces and poor come-up. Potato

foliage will not withstand freezing temperature, but frosted tops are readily replaced by new growth. Shoots branch below the level of injury, and new shoots may arise from hitherto dormant eyes.

Depth. Planting at a depth of about 4 inches is common and good. Shallower planting is desirable in heavy soils. On unirrigated lands, level covering is generally desirable. Ridging may be useful in heavy soils, for early plantings or where drainage is poor. It is more generally practiced in the south where cold wet soil may prevail at planting time. Ridging also makes for easier digging and protects from sun-greening. On the other hand, ridging increases the soil temperature, and the danger of root damage in cultivation. It also increases the soil surface with consequent loss of moisture. Tubers tend to form at about 4-inch depth, whether the seed piece is placed above or below that level.

Methods of planting. Planting of small areas is readily done by hand. Carrying seed in a bag slung around the shoulder is much less tiring than using a pail or basket. Covering is easily done with a plank drag or shovel-tooth cultivator.

Machines of two types are used on larger areas. *Picker* machines have a wheel with pins or points that stab the seed pieces as it revolves vertically through a hopper. As the wheel goes around, the piece is forced off into the planting tube by a pair of fingers. This type of machine requires only one man but is less certain in placing a piece at every spot than the *plate* or *platform* type. In that type there is a horizontally revolving plate with cells for seed pieces, which drop through as they come to the planting tube. A man rides behind to see that there is a piece in every cell. Two-row planters are now widely used.

WEED CONTROL

The time to control weeds is when they begin to grow. Early plowing and fitting and reharrowing before marking out are good practices, for this reason. After potato shoots are above ground, and have hardened up somewhat, a spring-tooth weeder, a rotary hoe, or even a spike-tooth harrow is used, going right over the plants in the rows.* Weeding crosswise while plants are

* See Figs. 12.9, 12.10, and 6.4.

small destroys weeds in the rows; it does a thorough job very rapidly with surprisingly little harm to the plants. It is better to use weeders and harrows when plants are slightly wilted.

As plants become larger, horse- or tractor-drawn cultivators are used, destroying weeds thoroughly but avoiding deep working of the soil which would cut roots. Stuart (*USDA Farmers' Bul.* 1064) says, "A single cultivation when the soil is filled with roots may, in the absence of rain soon after cultivation, reduce the yield fully one-half."

Soil is sometimes thrown toward the rows to smother weeds and, later in the season, to prevent exposure of tubers to sunburn. Such ridging should generally be kept to a minimum for the reasons given above.

Chemical weed control is developing slowly, applying a dinitro spray just before sprouts come above ground.

IRRIGATION

Potatoes are grown both with and without irrigation. In Idaho, Colorado, and California, irrigation is usual, mostly by furrow methods. Artesian water is used in the Hastings and Manatee sections of Florida.

Increased interest is being shown in irrigation for potatoes in the northeast, mostly by means of portable pipe and rotary head systems. Henry Talmage, of Long Island, a pioneer in potato irrigation, found that an average annual increase in yield of 15 bushels per acre could be expected to meet costs of operation, interest, and depreciation.

When potatoes are irrigated by the furrow method, ridges must be high and even, so that flooding of the upper surface of the soil may not occur. Metzger (*Colo. Sta. Bul.* 446) recommends that water enter the ridge below the seed piece to prevent puddling of soil around the tubers. His discussion of irrigation is thorough and enlightening on a topic that is necessarily rather vague. He recommends thorough irrigation before planting, then not until after the plants are up.

A steady supply of water is necessary for good potatoes, as quality and yield are both dependent upon steady growth. Lack of moisture at tuber-setting time is serious in itself and also because the soil temperature is likely to rise too high. After

that, a dry period followed by irrigation results in growth cracks, knobby tubers, and reduced yield. Metzger says that water is applied by Colorado growers from two to fourteen times, the average being about seven times. Definite rules cannot govern, but experienced growers learn to judge by the color and appearance of vines as well as by examining the soil. Irrigation should cease when tubers begin to mature.

DISEASE AND INSECT CONTROL

Definite programs for disease and insect control worked out by specialists and growers in the various regions should in general be followed faithfully. For large acreages, spraying is common practice; but for small plantings, dusting is more convenient. Dusters may be of the hand type for the kitchen garden, the knapsack type for larger home plantings, and the wheelbarrow or mule-back types for greater areas. In large commercial fields, huge machines spray or dust twelve or more rows at a time. See Chapter 13.

Diseases

Late blight, caused by *Phytophthora infestans,* is the most common and serious fungus enemy of potatoes, more prevalent in the north than in the south. The original infection is usually from planted tubers, as the fungus does not live over in soil or refuse. Once established it spreads freely, especially in cool, humid weather. The disease appears first as water-soaked areas in the leaves and may be confused with tip-burn. Mold-like growth appears on the under side of leaves.

Leaf damage is severe; the fungus also invades the tubers and causes a serious storage rot. Usual control is by the faithful use of Bordeaux spray, copper lime dust or carbamates.

Early blight, caused by *Alternaria solani.* The fungus winters over outdoors. A dark brown spot appears on the leaf and enlarges by concentric circles, damaging foliage as in late blight. It does not occasion tuber rot. The carbamates have given better control than copper.

Rhizoctonia or black scurf, caused by *Corticium vagum,* or *Rhizoctonia solani.* The fungus winters on tubers and in soil. It does its most serious damage to young plants, destroying or

weakening them, and lowering yields far more than is generally realized. It causes a black scurf on tubers that disfigures them and reduces their grade under U. S. standards, although actual damage to the usability of the potatoes is slight; it comes off in the peeling. Control is by seed treatment with organic mercury compounds.

Scab, caused by *Streptomyces scabies*. The fungus winters over in the soil and makes scabby lesions on the tubers. Its damage is mostly in marketability of tubers; here again, the harm is not much more than skin deep although grade is reduced by serious infection. Scab is favored by soil-reaction range from about *p*H 5.6 to 7.0. Keeping the *p*H between 4.8 and 5.4 and using scab-resistant varieties are the best means of preventing this disease.

Virus diseases of potato are a constant and serious menace, everywhere reducing yield and injuring the quality of tubers. They are caused by substances known as virus, which are transmissible from plant to plant and will develop within the plant, but yet have not been isolated or cultured. They do not lose their virulence in passing through the finest filters, in contrast to bacteria and other organisms which are readily filtered out of a suspension.

The virus diseases of potatoes are many and varied, each having symptoms recognizable by trained observers. Among them are mosaic, leaf roll, spindle tuber, yellow dwarf, and mild mosaic. Control is by use of virus-free seed, usually certified.

Black spot is characterized by darkened areas beneath the skin of uncooked tubers and is not to be confused with after-cooking darkening of potatoes. The cause of black spot is unknown. It occurs only after potatoes are bruised. Careful handling and heavy potash applications are helpful.

In various parts of the country, other diseases may be serious, among them fusarium or wilt; black leg, a bacterial disease; and ring rot, a more recent development.

Insects

Colorado potato beetle, *Leptinotarsa decemlineata* (species name means ten-lined). This is a true beetle, about ⅜ inch long, oval, with hard wing covers marked by yellow and black stripes. The larvae, which do most of the damage to foliage, are

dark red with black spots. Eggs are orange-yellow, in clusters on the under sides of leaves. The insect winters as an adult in the soil, and there may be several generations in a season. Control is by means of DDT added to spray or dust as applied for disease control. Where disease is not a problem, DDT alone serves well.

Flea beetle, *Epitrix cucumeris,* is a little black fellow, equipped for jumping like a flea, that eats holes in leaves, beginning as soon as potatoes come up. Larvae may also cause some blemishing of tubers. Control is by DDT as above.

Leaf hopper, *Empoasca fabae,* is a sucking insect, 1/8 inch long, which feeds at the tips of leaflets and causes tip-burn. Its ravages are more serious in dry seasons. Use DDT as above.

White grub, *Phylophaga* spp., **wireworms,** *Agriotes* spp., are more troublesome when potatoes follow sod. They damage tubers seriously. Suitable rotation and soil treatment with chlordane are recommended for wireworms.

Golden nematode, though common in Europe, has so far been found only on Long Island, New York, and in New Jersey. Long rotation seems to be the only control so far.

Vegetable weevil in the south, **blister beetles,** and other insects are sometimes troublesome **Aphids** are controlled by malathion or parathion sprays or dusts.

HARVESTING AND MARKETING POTATOES

Points to be considered in harvesting and marketing potatoes are:

1. Judging maturity.
2. Digging.
3. Picking.
4. Sorting.
5. Cleaning.
6. Bagging.
7. Storing.
8. Shipping and selling.

Harvesting

Judging maturity. Early potatoes are often dug before full maturity has been reached, while the skin is still tender and easily broken. Such potatoes on the market are easily recognized by the fluffed and curled fragments of skin. The tubers are edible at any time, and the question when to dig must be settled by balancing carefully present yield, prices, and market

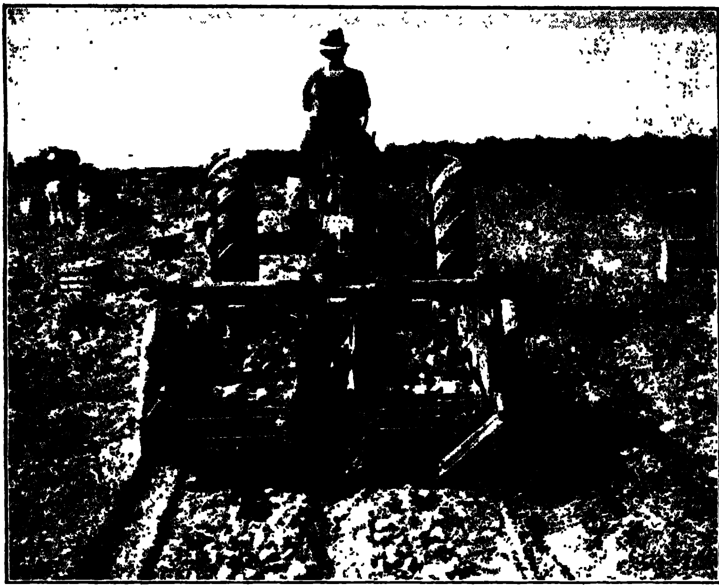
conditions against probable future prices and demand and the rapid gain in bushels per acre arising from the continued growth of healthy vines. If vines are badly diseased and dead or nearly dead, the gain is slow or negligible. Sometimes in early summer the supply of shipped-in potatoes may decline and prices may even increase with advancing weeks. Healthy potatoes that are not uncovered will keep for weeks in the soil, if wet or freezing weather does not occur.

If potatoes are to be dug at full maturity, they should be left until the vines have died down and the skin is well ripened so that it will not be easily cut, scarred, or bruised. This procedure also assures maximum yield. On the other hand, in northern sections growers do not like to delay unduly on account of the danger of freezing and of rains which may wet the soil and prevent digging or result in muddy potatoes. If late blight is present, it is well to let the vines die down fully, as danger of exterior infection of tubers is thus reduced.

Vine killers. Modern cultural methods result in the persistence of heavy vine growth up to digging time. Dinitros and sodium arsenite are used as chemical vine killers, and mechanical beaters are even more commonly used. This is primarily a matter of convenience for digging and picking.

Digging. Most commercial potatoes are now dug by machine. In small plantings and in the home garden hand digging is usual. Plowing out is also practiced on a small scale. Whatever the method, the utmost care must be exercised to avoid several kinds of mechanical injury. If the digger is not set deep enough, some tubers are cut or left in the ground. If the machine is not properly designed and adjusted, bruising will occur, not very apparent at the time, but resulting in serious blemishes. Ample power is important so that a digger of adequate width, up to 24 inches, may be used and so that it may be set to adequate depth. Diggers may be powered from the tractor.

Picking. Potatoes should be allowed to lie in the open air for an hour or two after being dug to permit the skin to dry and so to become somewhat more resistant to mechanical injury. Picking is usually done by hand into bushel crates, or baskets, strongly made for heavy service and long life. Some workers wear a heavy belt with hooks on which is hung a bag that drags on the ground between their feet; this makes for very rapid



John Deere Company

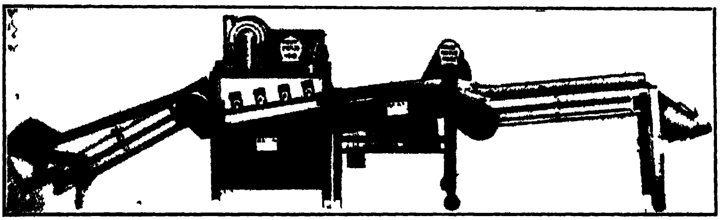
Fig. 16.5. Modern potato digger powered from tractor.

Fig. 16.6. Potato combine. Digger, sorting table conveyor, and truck with conveyor-bottom for unloading. This was a field-day demonstration.

picking. Mechanical pickers, or "combines," provide for delivery of tubers from the digger belt into crates or bags. A sorting belt is often included. Constant watchfulness is necessary to see that workers do not throw or drop the tubers even as much as 6 inches. The boss may even have to watch his own performance occasionally. Mechanical loaders save much labor.

Preparing for market

Sorting. Buyers are increasingly unwilling to accept potatoes that involve serious waste in preparation or that are unattractive in appearance. Hence a greater proportion of potatoes each year is sold as U. S. No. 1. Specifications for these may be had



John Bean Company

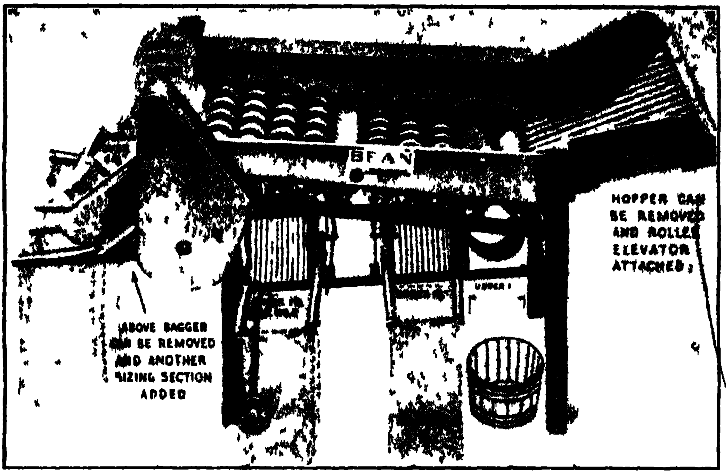
FIG. 16.7 Potato brusher and sorter.

from the U. S. Department of Agriculture or from state departments of agriculture. The U. S. standards specify minimum sizes for the various grades, but, within a grade, sizes may be stated in terms of diameter or weight.

It is often economical to eliminate culls and separate low grades before the expenses of packaging, transportation and handling have been incurred. Tubers that are clearly below marketable grade are well left in the field or picked up for feeding purposes.

Sizing is accomplished by hand or by machines, usually with belts or chains having openings of appropriate sizes. Sorting for grade is done by hand, often with the assistance of conveyor belts. Sometimes defective tubers are removed as they pass over sizing belts.

Manufacturers offer various devices which may be linked together to take care of washing or brushing, sorting for size and grade, bagging, and sewing. Some of these set-ups are within reach of a farm with a sizable potato enterprise; others are large



John Bean Company

Fig. 168 Sizing machine with rubber spools

Cornell University

Fig 169 Good display and signs help move 4-H potatoes in paper bags

and elaborate, for use by very large producers, dealers, or co-operatives.

Cleaning. Housewives are becoming more and more insistent that vegetables be clean when they buy them. They are not especially enthusiastic about dust on the clothing, dirt in the kitchen, and mud in the sink. Hence an increasing share of potatoes are now either brushed or washed before bagging. Equipment is available for this work on either a large or small scale.

Bagging. Potatoes are commonly sold in 50-pound or 100-pound bags of paper or burlap, printed or not. Second-hand bags, sometimes reconditioned, are widely used, but the trend is toward bright new containers Bags of cotton and of woven paper twine have their advocates.

Consumer packaging. Consumer packaging for retail sale is now generally the rule; it eliminates extra handling and loss or waste in the store, and, by carrying the trademark to the housewife, it helps to build a reputation for a brand. Small packages cost a little more per car, and the packer is usually able to profit just about that much, achieving his gains in readier sale and establishing his brand.

Consumer packs commonly take the form of 10- and 15-pound bags with some 5-pound. Strong printed paper is widely used, but other materials are also employed. The 4-H clubs of New York have been successful with a brand of their own for the product of project plantings.

In many cities peeled potatoes are available for restaurants.

Storage. See Chapter 14. The potato is the most important of all vegetables and is the most extensively stored. A third to a half of the crop of the northern late potato states is in storage up to January 1.

Careful experiments have shown not only the desirable conditions for the storage of potatoes but also what happens within the tubers and the conditions that govern these life processes.

The major requirements for successful storage of potatoes are (1) sound tubers, (2) a temperature between 36° and 40° F., and (3) a humidity of about 90%. If the storage place is too warm, serious loss by sprouting as well as by other shrinkage occurs.

Sprout-inhibitor chemicals have been explored, but so far none has come into common use. Proper storage conditions have usually provided adequate control of sprouting.

If tubers are bruised, cut, or infected with decay organisms, notably the fungus of late blight, they are likely to deteriorate rapidly. Healed cuts are less serious than unhealed. Storage is costly, and one may or may not gain enough in price to cover those costs. Hence it is wasteful to store potatoes or any other product that is diseased, blemished, or otherwise of low value when put into storage.

If potatoes are kept at temperatures under 36° F., they tend to become sweet in taste because starch is changed to sugar more rapidly than sugar is consumed in respiration. Keeping potatoes for a week or two at room temperature will usually eliminate this condition.

The storage place. Most storing of potatoes is done in the northern states where refrigeration is not necessary and where the climate is such that house, barn, and bank cellars may be kept sufficiently cool by natural means. Experiments have shown that bank cellars built of concrete and covered with earth serve well. Converted barns and other buildings may be used. Designs may be found in agricultural engineering books or bulletins or may be obtained from cement companies. House cellars are likely to be warmer and drier than is desirable. Well-insulated buildings above ground, remodeled barns or other buildings, are becoming increasingly popular.

Most growers store in large bins. It is well to have a slat floor slightly raised from the earth floor and to put up a slat wall a few inches from the wall of the storage place to permit free circulation of air. Fans and ducts are often used to provide thorough circulation.

Convenience and labor saving in handling potatoes in and out are important. Arrangements to drive into the storage place and the use of bin loaders are desirable. Some use is made of large crates to be handled with powered lift trucks.

Temperature and ventilation. The storage place should be so arranged that doors or ventilators may be opened and closed to adjust the temperature. In the fall, newly dug potatoes respire actively, generating heat. It is necessary to keep the place open during cool nights and closed by day. In the winter, if

temperature threatens to go too low, the room may be opened during a warm day. If this is not sufficient, a charcoal or coke "salamander," such as builders use, may be installed. Such a heater may be made from an old oil drum or milk can. Potatoes will usually give off enough moisture to keep the humidity up if the space is well filled and there is not too much circulation of outside air.

Fluctuation of temperature is especially bad. Evaporation from the tubers is hastened when it is warm; then, when the temperature falls, the moisture is condensed and wets the potatoes. If the alternation is wide and often repeated, there is serious loss in weight of the potatoes and their quality is impaired by shriveling and shrinking. Good outside insulation with earth or straw is an effective preventive measure.

Shipping and selling. See Chapter 4.

CONCERNING THE POTATO

Food use

The Irish potato is one of the world's great food-producing plants. It is primarily a carbohydrate or energy food with 18% starch and other carbohydrate, 2% protein, 1% ash or mineral, and 78% water. The heavy yield per acre enhances its value as a food plant, although it is not stored as readily or as long as the cereal grains.

The potato is cooked and served in many ways: baked, boiled with jackets on or off, fried, escalloped, mashed, or as salad.

Potato chips have become important as an outlet. Suitable varieties grown under favorable circumstances are required for this purpose, and the chips must be prepared under carefully controlled conditions.

Table quality. Aside from appearance and characteristics that involve waste in preparation and use, potatoes are judged on two internal characters that cannot be discerned on casual examination: *mealiness* in contrast to sogginess, and *blackening* on boiling.

Factors affecting mealiness are not well understood, but there is reason to believe that percentages of dry matter and of starch and *p*H of tissue are involved as well as hereditary differences.

Smith, Nash, and Dittman (*Am. Potato J.*, *19*:229–254) have found that samples of potatoes which have matured at air

temperatures of about 60° F. are more disposed to blackening on cooking than those that have matured at about 70° F. If tubers that blacken are stored at a temperature of 100° F. for 3 or 4 days the trouble is reduced. There seems to be a relation between high *p*H of tissue and blackening.

Potatoes are sometimes separated into specific-gravity classes by means of salt solutions of standard strength. Those of specific gravity above 1.080 are mealy and good bakers; those below s.g. 1.080 are less mealy, sometimes spoken of as soggy, and suitable for boiling. A machine has been devised to make the separation on a continuous basis. This method of grading has not yet been widely adopted.

Botany

The potato, *Solanum tuberosum,* belongs to the family Solanaceae, along with the tomato, pepper, eggplant, tobacco, petunia, belladonna, nightshade, and jimson-weed.

The potato plant is a herbaceous annual, propagated by planting tubers which are thickened portions of underground stems called stolons. Eyes are groups of buds, one or more of which develops into shoot and stem.

The root system is described by Weaver and Bruner (see ref. 4 of Chapter 7) as rather superficial, mostly in the upper 8 inches of soil during early growth. Roots extend laterally, then downward, reaching a depth of 2 or 3 feet. There is very thorough branching and rebranching but no very strong taproot or heavy branches.

Plants ordinarily reach a height of 2 or 3 feet, usually falling over as growth advances. Varieties differ in habit. Leaves are compound.

Flowers about an inch in diameter develop freely on some varieties, not so freely on others.

Fruit, not commonly developed, is a little berry, with seeds about 1/16 inch in diameter. Potatoes are highly heterozygous; that is, they have not been bred to pure lines and seedlings show the wide variations that would be expected from a vegetatively propagated plant. Seedlings have furnished much valuable breeding material.

Importance

In the United States we planted under 1.5 million acres of potatoes in 1950, as against an average for 1941–1950 of 2.4 million acres. Harvest came to about 325 to 350 million bushels compared with 415 million, the 10-year average; the average yield per acre was over 240 bushels, having risen from about 84 bushels in the nineties; for the years 1941–1950 it was about 180 bushels. Per capita consumption declined markedly from 190 pounds in 1909 to 108 pounds in 1949. Possibly this reflects the use of a wider variety of other vegetables by more people. See Chapter 1.

The most important potato states, in terms of production, are Maine, California, Idaho, and New York, each producing over 30 million bushels a year, 10-year average The farm value of the crop is from $400 million to $500 million annually. Leading early states are California, North Carolina, Florida, and Alabama. Virginia and New Jersey are important intermediate states. Potato statistics do not discriminate between production for home use and for market. For full data see *Agricultural Statistics,* issued annually by the Department of Agriculture.

For a few years the potato crop was planted under a government control program which was very costly, encouraged overproduction, and resulted in serious waste which the public resented. Growers themselves voted the plan out in some areas, and its operation ceased in 1952.

Yields, costs, returns

The average yield per acre of potatoes does not represent a successful crop unless prices are high. Yields of 400 bushels per acre are common and 600 bushels no longer unusual. Weyl-Zuckerman, with hundreds of acres of potatoes in the Sacramento delta, has reported 1,160 bushels from a measured acre. L. G. Schutte of Colorado grew 1,145 bushels on an acre.

The average wholesale price in New York has ranged from 58 cents per bushel in 1934 to $2.84 in 1919 and $2.47 in 1951. When the total crop rises much above 375,000,000 bushels, prices in normal times are likely to be low, though business prosperity and public buying power are important factors. As with other

crops, a relatively small surplus results in a disproportionate and often disastrous reduction in prices.

Considered among vegetables, the potato is relatively cheaply produced, on a bushel basis, varying, of course, with the regions and seasons.

Histoty

The potato is clearly of new world origin, perhaps of the Andean section of South America. It was probably introduced to Europe during the sixteenth century. Very likely the Indians of North America did not know or use the potato until after European exploration. It may have come to northern America by way of Europe.

The potato became an important food plant in the United Kingdom and continental Europe late in the eighteenth century. Germany, Poland, and Russia far exceed the United States in potato production and use. Yields per acre in Europe generally exceed those in the United States. In 1952, for instance, the average yield in Holland was 363 bushels, in Germany 309 in contrast to 249 for the U. S. Italy, on the other hand, only had 109 bushels per acre.

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17

Sweet Potato

In the South the word potato is likely to mean the sweet potato, the white potato being called that or Irish potato. The sweet potato is a southern crop but not as southern as most people think. The principal sweet potato states extend from

FIG. 17 1. The sweet potato is a southern crop, but satisfactory yields for home use may be expected from Massachusetts to Iowa Here are six varieties in central New York

North Carolina to Texas, but New Jersey, Missouri, and California report 3,000 to 15,000 acres annually.* Although the sweet potato is not likely to become commercially important farther north than Missouri, crops for home use may be matured with reasonable yields in states like Ohio, Oregon, Michigan, and New York, three or four years out of five. And sweet potatoes supply mighty fine eating. Northerners have to pay substantial prices for good southern sweet potatoes.

* States from Texas to North Carolina grow from 40,000 to 100,000 acres each.

The sweet potato is among the first vegetable crops in importance. It is a major food crop for home use in the south, and a smaller percentage of total production reaches trade channels than with any other important vegetable. However, commercial shipments have increased greatly, especially in Louisiana.

Preference for the soft or firm types of sweet potato is largely a personal or family matter, but the soft varieties are almost universal in the more southerly states and their use is increasing in the north; as some would say, the northerners are learning what is good to eat.

The sweet potato is of some importance in animal feeding, and some progress has been made in its culture and processing for use as starch.

Sweet potatoes are canned in limited volume. Ways of making snacks and confections from sweet potatoes were devised by George Washington Carver of Tuskegee, and the methods have been further developed by the Alabama Experiment Station.

ADAPTATION

Climate. The sweet potato is sensitive to frost, requiring a warm sunny growing season with 160 days or more without frost. On a non-commercial scale, roots will mature in a little less, say 105 to 120 days. For example, plants set the last week of May at Ithaca, N. Y., have usually made good roots by mid-September. The crop is tolerant to heat and moderately tolerant to drouth.

Soils. Sweet potatoes are at their best in friable well-drained soils, usually sandy to sandy loam. Some are grown on very sandy soils even though nutrients are low. Heavy and overrich soils are said to yield poorly of low-quality roots.

The sweet-potato grower should have facilities for starting plants and for storage of roots.

SOIL MANAGEMENT

Sweet potatoes are well grown in a rotation which maintains organic matter in the soil. Rotation aids in curbing disease losses. The sweet potato thrives through a wide range of soil reaction, say *p*H 5.0 to 6.8, and liming is seldom required.

Stable manure is not commonly used for sweet potatoes, being more valuable for other crops. Commercial fertilizers should be used according to local recommendations, ratios ranging from 1–1–1 to 1–4–1, the latter for heavier soils. It is not customary to use more than 500 to 600 pounds of a 16- to 20-unit fertilizer (5–6–7 represents 18 units).

Fertilizer is commonly placed near the row, sometimes worked into the row a week or two before setting, sometimes applied along the row after setting and cultivated into the soil. Special care must be taken to avoid bringing fertilizer into contact with roots as they are very sensitive to injury.

The potash requirement of the sweet potato has been the subject of much experimentation and some controversy. Schermerhorn found some years ago that the liberal use of potash favored good yield and shapely, chunky roots. Boswell in South Carolina and Miller in Louisiana have not supported this contention. Probably response depends upon the need for potash in various soils. See refs. 2 and 4.

Additions of magnesium are sometimes required, especially in sandy soils. Some writers mention overgrowth of vine and misshapen roots as resulting from overuse of nitrogen.

VARIETIES

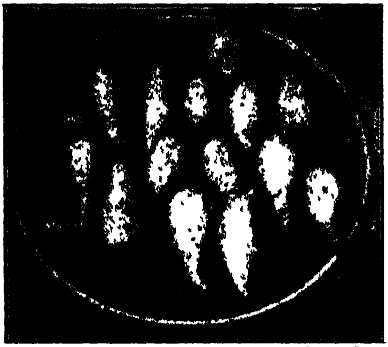
A good sweet potato variety is:

1. Vigorous in growth but not too wide spreading. There are now good dwarf varieties.
2. Resistance to disease, especially to *fusarium* or *stem-rot*.
3. Heavy yield.
4. High percentage of medium-sized, moderately chunky roots, of uniform shape and smooth surface.
5. Deep orange color of flesh and skin, indicating a high content of carotin.
6. Free of stringiness, firm or soft flesh when cooked, as desired, sweet, and free of rank or disagreeable flavor.

In 1922 Thompson and Beattie[5] published a thoroughgoing study of sweet-potato varieties, describing and classifying the widely varied sorts into eight groups. This classification still holds, but with new varieties being developed by hybridization and selection a new study is needed. See ref. 2.

The Jersey group includes firm-fleshed sweet potatoes as grown principally from North Carolina to New Jersey and to some extent in the middle west. Included are **Yellow Jersey, Red Jersey, Big Stem Jersey,** and **Gold Skin.** Yellow Jersey has small, slender, green vines, yellow roots, and yellow flesh. **Maryland Gold** and **Jersey Orange** are improved strains.

Puerto Rico is the leading soft variety, widely grown in the south for home use and for shipment. Vines are vigorous, coarse, and tinged with reddish purple. The skin is rose and the flesh salmon in color and of



Alabama Expt. Sta.

FIG. 17.2. Puerto Rico is the leading southern variety of sweet potato.

excellent table quality. **Unit 1,** selected by J. C. Miller, is probably the leading strain. **Cliett Bunch** and **Murff Bunch** are good strains with short vines.

Nancy Hall is also soft when cooked. Vines are green, roots yellow, flesh a dark yellow.

Allgold is resistant to stem rot, high in vitamins, heavy yielding, and of fine quality.

Southern Queen and **Triumph** are of sandy or straw color and of lower quality though planted to some extent in the south. They become important for industrial starch because of high yield and high starch content.

Soft-type sweet potatoes are often called yams, especially in stores in the north. The true yam is a tropical plant with edible root belonging to the genus *Dioscorea.* It is to be found on New York markets, being popular with people of West Indian origin.

PRODUCTION OF PLANTS

The sweet potato is propagated by transplanting shoots, sets, draws, or slips, as they are variously called, which have grown from adventitious buds on roots that have been planted in beds for the purpose. *Vine cuttings* taken from plants after they

have become established in the field are also used where the season is long enough. These are planted like slips, and soon throw out adventitious roots. Thus the original plant bed is made to supply from one-eighth to one-fifth of the total quantity of plants required; the remainder are from vine cuttings.

Another method recommended (*La. Sta. Bul.* 281) as a precaution against disease transmitted from the bedded roots is to plant the roots in rows in the field and take vine cuttings from the resulting plants instead of pulling slips. Planting of seed pieces as for Irish potatoes has been suggested. It is pointed out that taking vine cuttings tends to reduce the yield of the plants from which they are removed.

Use of heat. In the more northerly sweet-potato areas, plants are grown in greenhouses or more commonly in hotbeds heated by manure, hot-water pipes, or fireplace and flues. Nissley gives detailed directions (see ref. 5 in Chapter 9). Bottom heat is desirable. In the far south, beds are planted in the open, but in mid-south a shallow manure hotbed may be made, covered with canvas instead of sash.

Disease-free seed roots and soil are very necessary as precautions, especially against stem rot and black rot. Roots are commonly treated with mercuric chloride (corrosive sublimate), 1 ounce to 8 gallons, for a period of 5 to 10 minutes before planting. Metal vessels are attacked by the solution and should not be used. The material is a deadly poison, and proper precautions for safety must be taken. Organic mercury and other organic fungicides may be used according to directions.

Soil should be sandy and need not be rich as the plants draw upon the parent roots for material for growth.

Roots are spaced in the beds just far enough apart not to touch, with soil filled in between. They are covered 1 to 2 inches deep. When shoots begin to appear, an inch or two of additional soil is added to insure sturdy, well-rooted plants.

Soil temperature of about 70° to 75° F. is desirable, and air temperature should be 70° to 80° F. Severe chilling should be avoided. As in other plant growing, watering should be gauged to give a stocky plant that is not tender and easily broken. During later growth, water will be withheld just enough for proper hardening of the plants.

When to make the bed. Plant beds are made up five or six weeks before frost danger is past. Even where the season is long, experiments [36] have shown that each week of delay in field setting is likely to result in a loss of as much as 25 bushels per acre in total yield.

How large to make the bed. An acre of sweet potatoes in the field, spaced at 3 feet by 12 inches, will require about 14,500 plants. Six or eight bushels of roots bedded in a space 6 feet by 25 or 30 feet will give plants for an acre at a single pulling. Additional pullings or drawings may be made a week apart if the season is long enough to permit the delay. In this case about half as many roots may be bedded per acre. A bushel of small roots yields more slips than a bushel of large ones and gives as good a crop if they have been saved from a good strain.

PLANTING IN THE FIELD

Sweet-potato plants are pulled from the plant beds, since they part readily from the planted root. It is well to hold the parent root down with one hand so that it is not lifted with the young plants.

Plants should be protected carefully from drying out between pulling and setting. If the soil is dry, puddling or dipping the roots in thin mud is a good practice. The mud coat should not be allowed to become dry.

Spacing. The field is marked out with rows 3 to 4 feet apart, adjusting according to variety, soil fertility, and moisture supply. Spacing in the row varies from 9 to 18 or 24 inches. Close spacing is desirable in rich soil; otherwise roots are likely to be too big, a serious market defect.

Where necessary for good drainage and aeration, some ridging may be practiced, but a broad low ridge is better than a high narrow one, and level culture is still better if feasible. Ridging exposes more soil surface for drying out and increases the danger of cutting roots in cultivating.

Setting the plants. Plants are set or transplanted by hand as with other crops, and this practice is satisfactory for the home garden. In larger fields, the spade method is good. One person sets a spade into the soil; another places the plant in the wedge-shaped opening as the spade is withdrawn. The first worker

then steps on the soil to firm it about the roots and stem. In the dibber-and-tongs method, one person drops the plants, and a second comes along, holding in one hand a dibber or a narrow piece of board sharpened to a flat point with which a hole is made. The other hand works a pair of tongs to pick up the plant and place it in the hole. Then foot pressure finishes the job. This is a rapid method and avoids back-breaking stooping. In large fields transplanting machines are sometimes used as for cabbage and tomatoes.

Vine cuttings 15 or 18 inches long are set in the same way as slips, or the middle of the cutting is simply pressed into the soil with a stick, then the earth about the stem is pressed with the foot, and the stem soon strikes root.

LATER CARE

Cultivation. Shallow cultivation sufficient to control weeds is necessary; more than this is a waste of labor and may be damaging. Vines are sometimes moved to permit late cultivation, but if rooting has occurred this is harmful, more so as the season advances. If the weeds have been kept down and growth is vigorous, weeds have little chance. Some hoeing while plants are small is often required to keep weeds under control.

Pruning of vines, though sometimes practiced, is definitely harmful. It is the vines that make the material for the edible roots.

Irrigation of sweet potatoes is not usual in the south. In the southwestern states, where it is necessary, water is usually applied by the furrow method. Specific rules cannot be laid down, but overwatering is to be avoided, especially after vines cover the ground, as diseases may be favored and overlarge and misshapen or cracked roots are likely to result as well as overgrowth of vines. This matter of balance between vine growth and root development seems not to have been studied.

DISEASES AND INSECTS

The most serious sweet-potato diseases attack the root and stem rather than the leaves, so that spraying and dusting are

not important. Black rot and stem rot are the most widespread and destructive of sweet-potato diseases.

Black rot, caused by *Ceratostomella fimbriata,* attacks all underground parts and is damaging in both field and storage. It lives over in sweet potato or other organic matter in the soil and in roots in storage. It appears on stems as small, dark spots which finally rot off the whole stem. On roots it appears as round, dark, slightly sunken spots which spread and may involve the whole potato. The disease imparts a disagreeable bitter taste. It spreads in storage, but use of infected roots or infected soil for plant growing is the most serious means of spreading black rot.

Control of black rot requires use of clean soil for plant beds, selection of disease-free roots, and treatment of roots with bichloride of mercury, as suggested above.

Stem rot is a field disease caused by a fungus, *Fusarium* spp., of the great *Fusarium* group, the members of which are persistent in the soil, causing internal infection, darkening and clogging of vascular tissue, and wilting, yellowing, and death of the plant. Dark rings in stem cross sections are characteristic of the whole group and of stem rot in sweet potatoes. Stem rot is more serious in the central and northern sweet-potato areas than in the far south as the fungus does not thrive at temperatures above 90° F. It is carried over in storage, though it does not cause a serious storage rot, and is spread through the plant bed. Basal leaves of plants become yellowed and drop, growth is checked or stopped, wilting appears, and plants gradually die. If infection occurs late, the plant may survive but growth and yield are reduced.

Control is by (1) careful selection of tubers from vines proved to be healthy by examination of stems for darkening of vascular tissue; (2) use of clean soil in the plant bed; (3) treatment of roots before bedding (bichloride of mercury); and (4) choice of resistant varieties. The Jerseys are susceptible; Puerto Rico and Southern Queen, resistant.

The sweet potato is subject to many other diseases. Harter [8a] describes them fully and clearly, giving control measures. For a more technical treatise on organisms and control, including an extensive bibliography, see Harter and Weimer.[8b]

The sweet potato weevil, *Cyclas formicarius,* is the principal insect enemy, especially in the Gulf states. It is a slender snout-beetle, about ⅛ inch long, somewhat resembling a large ant. It breeds the year around in field or storage. The principal injury is caused by larvae or grubs which burrow in the roots and by adults feeding on leaves and stems.

Control. (1) Clean up fields thoroughly after harvest. Pasturing hogs helps. (2) Dispose of all roots early in the fall, or store under carefully controlled conditions to prevent the escape of infested material to the land. Clean the storage place thoroughly a month before storing time. (3) Bed only weevil-free roots. Fumigate seed stock with methyl bromide. (4) Use vine cuttings. (5) Practice crop rotation. (6) Keep the field clear of volunteer sweet-potato plants and certain forms of the morning-glory family that harbor the insects. (7) In saving roots for seed, inspect carefully for infestation and store separately. (8) In storage dust with 10 per cent DDT and keep temperature high for a longer time than is necessary for ordinary storage. (9) Observe plant quarantine regulations.

MARKETING

The sweet potato does not reach a definite condition of maturity as does the Irish potato, but may continue to gain weight indefinitely.

In harvesting, sweet potatoes should be handled more carefully than eggs. They are easily bruised and scarred, especially when newly dug, and even accidental fingernail cuts may admit fungus infection and cause loss in transit or in storage. Workers often use cloth gloves when handling sweet potatoes.

Judging maturity. Sweet potatoes, like Irish potatoes, may be harvested and sold as soon as they are big enough, but it must be remembered that they gain rapidly in total yield as they near maturity. The table quality of mature sweet potatoes is better than that of immature roots. When sweet potaoes are mature the cut surface dries quickly on exposure to air. Drying down or yellowing of vines or cessation of growth is due to lack of moisture or nutrients, to disease, or to cold, rather than to maturing of the plant as with Irish potatoes or wheat.

Harvesting. The best method of harvesting sweet potatoes has not yet been devised. One common form of digger consists of a plow, with rolling coulter to cut the vines and a short mold board and rods to lift the roots to the surface while soil falls through. Another common implement is a double mold board plow or "middle-buster." Whatever the method, great care must be exercised to avoid cutting and bruising the roots, which are more tender than those of Irish potatoes and more widely spread in the row.

Handling and sorting. Bright sunny weather is best for digging, and roots should be allowed to dry a few hours before picking up. If frost affects vines they should be pulled or cut immediately to avoid the passage of decay organisms into the roots.

For immediate shipment, sweet potatoes are usually sorted and packed in the field as it is difficult to put them through a packing house without serious damage. Some shippers sort, wash or brush, and pack sweet potatoes in a central packing house.

Most markets do not care for oversized sweet potatoes. Standards for U. S. No. 1 call for diameter between 1¾ and 3½ inches and length between 3 and 10 inches. The preference is for moderately chunky potatoes, and "strings" are not wanted.

Packages. Bushel baskets and bushel boxes, of wire-bound or sawn construction, are common shipping containers for the soft-cooking Puerto Ricos or Nancy Halls. Paper liners are commonly used to avoid scarring. The Jersey type of the Atlantic coast usually moves in bushel baskets or hampers.

STORAGE

Store only good potatoes. Storage of sweet potatoes is precarious at best. Hence there is no use storing damaged or diseased roots. Thompson and Beattie (*USDA Bul.* 1063) compared losses in storage in injured and uninjured potatoes, finding, respectively, 28 and 14% shrinkage at the end of 5½ months. Half this loss had occurred by the end of a 19-day curing period. Sorting is best done as the roots are picked up, perfectly sound ones being taken and others being left to be gathered later. Sorting after picking up and before storage did not reduce loss

sufficiently to justify the labor and damage involved, and the process may actually spread infections.

Curing is the term applied to a preliminary storage of roots at temperatures between 75° and 90° F. in a moist atmosphere, about 85% relative humidity. Curing is apparently a matter of healing or corking over of wounds. The period ranges from 10 to 28 days.

Lauritzen (*J. Agr. Res.*, *50*:285–329) has studied factors governing infection of roots. He finds mechanical injury the most important element. This may take the form of cutting, skinning, or abrasion and bruising. Formation of a suberin (corky) layer and development of wound periderm are important means by which damaged areas become less susceptible to infection.

Thompson and Beattie found that 50° to 55° F. is a better storage temperature than 55° to 60° or 60° to 65° F., though the differences were small. This is much higher than for most vegetables, probably because of diseases which thrive at relatively low temperatures. Internal physiological breakdown is likely to occur under prolonged exposure to temperature under 40° F.

Where to store. Great advance, dating from the work of Thompson and Beattie, has been made in sweet-potato storage, both for home and commercial purposes. Extension work has spread the knowledge of good storage methods, and designs for inexpensive houses are available in most southern states. Bank storage results in considerably heavier shrinkage than house storage, and in some years heavy losses are general and sometimes complete. Bank storage is useful for home supply if a better plan is not feasible, but small houses are simple and inexpensive and should be used wherever possible.

What happens in storage. Studies by Hasselbring and Hawkins [12] were concerned with the changes that take place during the storage of sweet potatoes. These changes illustrate the complex nature of the processes and the balances among them. Naturally moisture is lost during storage, but the percentage of moisture does not change greatly, for water is a product of respiration, and losses are partly replenished. Also total weight declines, for carbohydrate is consumed in respiration with carbon dioxide diffusing away and water escaping by evaporation. The percentage of starch declines, but the percentage of sugars increases. The softness on cooking of such varieties as Puerto

Rico is traceable to their higher sugar content. During storage, potatoes increase in softness of texture and in sweetness, owing to increase in percentage of sugar and decrease in starch. Culpepper and Magoon[12b] have shown that consistency depends

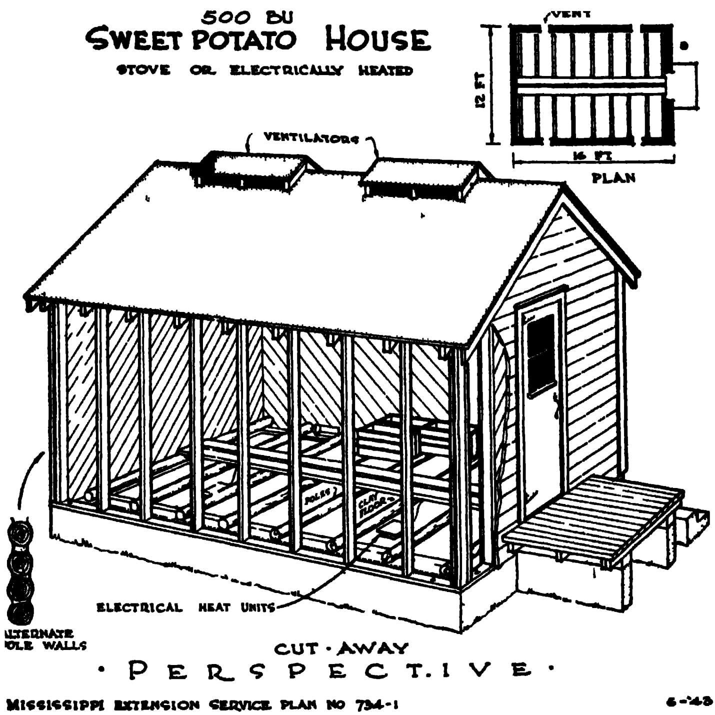


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FIG 17 3 Sweet-potato storage

upon the ratio of starch to moisture. As starch is changed to dextrin and sugar, the potatoes become sweeter and softer.

CONCERNING THE SWEET POTATO

Food value

The sweet potato carries less water and 60% more carbohydrate than the Irish potato. The calorie value of the former is 565, of the latter 385. The sweet rates with the Irish potato in content of vitamins B, C, and G but is much higher in vitamin A (carotinoid). Food value, easy culture, and keeping quality

have made the sweet potato a great food plant in the south, and appreciation of it is gaining in the north.

The sweet potato is commonly cooked by simple boiling, baking, or frying, and sweet-potato pie is a delicacy comparable to pumpkin pie.

Botany

The sweet potato, *Ipomea batatas,* belongs to the morning glory family, Convolvulaceae. It is a herbaceous branching vine with milky juice, annual in the United States, but it may live many years in the tropics or in a greenhouse. A plant which had grown four years in a greenhouse and yielded a root weighing 125 pounds has been reported.

Plants arise as adventitious buds on fleshy roots, usually at the base of a fibrous lateral root. Feeding roots appear at the base and along the stem. Roots develop on vine cuttings or on vines that come in contact with the soil.

The flower is like that of the morning glory with bell-like corolla. The capsule is of two cells, each of which bears two angular seeds similar to those of morning glory but smaller. The seed germinates with difficulty, scarifying or treating with sulfuric acid being necessary.

Blossoming seldom occurs naturally in the United States but is more common in tropical climates. J. C. Miller[7] has found that, by overwintering sweet-potato plants, setting them outdoors in the spring, training them to a trellis, and then girdling or partially severing the stem, blossoming is readily induced. He is inclined to discount but not to dismiss earlier indications that sterility is a serious problem. Miller's method has opened the way for improvement by crossing, whereas previous improvement has had to rely upon clonal selection alone. As a result of his work an extensive interstate breeding program is in progress, yielding important improved varieties.

Bud sports. The sweet potato is unusually subject to bud sports, or mutations, a single plant, for example, showing both white and red roots, and perhaps one or more roots showing two colors in lengthwise stripes or zones, sectorial chimeras. These mutations may involve characters other than color, and they afford a starting point for selection work.

Importance

The sweet potato is planted on a fourth as many acres as the Irish potato, and total production is less than an eighth as great. Farm value ranges from $85,000,000 to $95,000,000, about a sixth that of the Irish potato. More than half of this value is from sweet potatoes consumed on the home farm.

Louisiana has advanced rapidly as a commercial producer, being responsible for more than 25% of car-lot movement. These are soft-type potatoes. The Carolina to Jersey area ships mostly firm varieties, as does Iowa.

Yields and costs

The average yield for the United States is about 85 bushels per acre. The state average for Indiana is nearly 100 bushels per acre, but Gaylord and Cleaver (*Ind. Sta. Bul.* 370) report a three-year average for growers interviewed in four commercial counties as 170 bushels per acre. R. A. McGinty in 1929 conducted a contest in South Carolina in which the average yield of all contestants was 300 bushels per acre, and 176 bushels per acre of U. S. No. 1. The average acre yield in Missouri in 1952 was 155 bushels. Good commercial growers would expect at least 250 bushels per acre.

History

The sweet potato was observed by Columbus and his companions as an important food plant of the western hemisphere. It was soon carried to other parts of the world, and it is important in Asia and Africa but not in Europe. Sturtevant (see ref. 6 of Chapter 7) does not offer any evidence that the sweet potato was known in pre-Columbian times, but one can readily wonder if some other edible-rooted plant of the same family might not have been native and used in areas other than America.

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18

Tomato

I'm glad that when the summer heats
Have made me choosy in my eats,
Tomatoes come with ripe red skins,
Brimful of health and vitamins.

—Bob Adams.

The tomato is a warm-season crop. It is not only sensitive to frost but it does not thrive at low, non-freezing temperatures, say under 60° or 65° F. Successful commercial culture demands a frost-free season of over 110 days, but it is worth while to plant for home use on less. High temperatures, accompanied by low humidity and drying winds, frequently damage floral parts so that fruit does not set. In some regions or some summers, plants may set fruit in early and late clusters with failure between. The tomato withstands drouth fairly well but fruits are subject to blossom end rot and, if moisture supply follows drouth, to growth cracks.

The tomato grows on practically all soils from light sand to heavy clay; it grows on muck soils but not as well as on upland, and it tolerates fairly acid soils. Geographically, its range covers the country, thriving during New England and northwestern summers, during Florida winters, and in the various parts of California at all seasons. The tomato-canning belt extends from Maryland, New Jersey, and upstate New York through to California and Oregon. Some tomatoes are canned in the south.

In a backyard, with no room for a vegetable garden, three well-grown tomato plants will readily produce 30 or 40 or more pounds of tomatoes, and a 50-foot row will yield fruits to eat and to can.

Thus, there are few situations where the tomato may not be grown for home or market.

SOIL MANAGEMENT

Tomato lands should be well maintained in organic matter and well drained. Hester[6] suggests that sandy soils should have a minimum of 1.5% organic matter, sandy loams about 2%, and silt loams 3%. This is the principal consideration in shaping a rotation around tomatoes. Since plants are not set until the danger of frost is past, fall plowing is not important.

Although the tomato is acid-tolerant, Sayre in New York has found that liming is often beneficial. It may also be of value to favor growth of cover crops, or it may be useful in its effect upon nutrients and toxic materials in the soil.

Many states have issued publications bearing fertilizer recommendations which serve as a better guide for regional conditions than any general statement.

Nitrogen. An adequate supply of nitrogen is necessary to insure the good growth of vine which in turn must manufacture the material to be harvested. Sandy soils require more nitrogen than heavier soils. If manure is available it is unnecessary to use as much commercial nitrogen as otherwise. Choice of the form of nitrogen is largely a matter of price, except that an early crop in cold soil calls for at least part of the application to be in nitrate form.

Phosphorus. In most places, phosphorus receives first emphasis in fertilizer planning, nitrogen second, and potash third. A liberal supply of available phosphorus favors earliness.

When a complete fertilizer is used, ratios from 1–2–1 to 1–4–1 are commonly recommended, with the higher phosphorus applications on heavier soils and when manure is supplemented by fertilizer.

Manure gives good results, but it should be applied for the preceding crop rather than immediately before tomatoes are planted, especially if the manure is fresh. On well-maintained soils, 10 tons of manure plus 1,000 pounds of 18 or 20% superphosphate per acre may serve well, thus adding the equivalent of a ton of 6–12–6 in terms of nutrients, in addition to organic matter, minor elements, and perhaps needed organisms.

For cannery tomatoes, band placement of fertilizer is advisable, particularly if the total quantity used is to be small. When larger amounts are used (¾ to 1 ton), part should be broadcast

before plowing on heavy soils and *after* plowing on light soils. Then band the remainder.

Starter solutions at transplanting have proved useful in many situations. See page 185.

Side dressing with nitrogen has long been established practice on lighter soils, sodium nitrate or ammonium nitrate being applied along the row once or twice, up to the time of the last cultivation. This helps to keep the vines in growth and fruiting and contributes to a longer picking season and greater total yield. New Jersey workers have found that large-growing varieties such as Rutgers should not receive much nitrogen at planting time but that side dressing when the first or second cluster sets is profitable. Smaller growing varieties such as Valiant or Stokesdale need ample nitrogen from the first to promote early vine growth.

Skillful growers learn to judge nitrogen and other nutrient needs by the color and performance of plants.

Vegetation and reproduction, "running to vine," see page 104.

VARIETIES

Tomato varieties offer wide range in plant habit, in size, color, and shape of fruit, and in adaptation to various uses and regions.

Ideal. A good tomato variety possesses the following characters, subject to modification for various purposes and areas.

1. Vigor of vine to make a heavy crop and to protect the fruit from sunscald.
2. Resistance to disease, especially fusarium.
3. Heavy yield of fruit.
4. Earliness or lateness of maturity as required.
5. Suitable fruit size—uniformity is desirable for box and carton packing.
6. Round to oblong shape.
7. Deep rich color, evenly developed within and without.
8. Flesh that is abundant and firm with little watery pulp.
9. Resistance to cracking.

For authoritative descriptions of important varieties see Boswell.[4]

Victor and **Bounty** are similar, almost as early as Valiant and producing much fruit during the early weeks of harvest. Vines are short-branching and sparse, thus subject to sunscald in hot climates. Fruits are very light green before maturity (uniform coloring gene—*UCG*), flattened to almost round, smooth, regular, and well-colored. **Early Chatham** is smaller and earlier.

Valiant is perhaps the leading early tomato. Growth is rangy and sparse. The fruits are early, round, medium to large, smooth, but somewhat lacking in good color about the shoulder.

Early Hybrid (Earliana × Valiant), **Burpeeana** and others are early hybrid varieties. Midseason and late hybrids are also available. See page 114 on hybrids.

Stokesdale is an important northern main crop and processing variety, midseason in maturity, with moderately vigorous vine, and medium to large flattened fruits, smooth, well-colored, and fleshy.

Red Jacket and **Longred**, bred by W. T. Tapley of the Geneva, New York, Experiment Station, are main-crop varieties for the north. They offer heavy yield and fine quality for processing.

Marglobe, bred by the late Dr. F. J. Pritchard of the U. S. Department of Agriculture, is a midseason variety, resistant to fusarium and nailhead spot. Vine is vigorous, and fruits are nearly round, smooth, of medium size, and well-colored. It is susceptible to radial cracking. **Pritchard** is earlier and short-branching in habit.

Rutgers is the most important tomato variety for market and processing. Bred by L. G. Schermerhorn of New Jersey, it is an excellent main-crop

FIG. 18.1. Clusters of originator's stock of the Rutgers tomato.

tomato, but it matures rather late for northern states. The vine is vigorous and provides good coverage against sunscald. Fruits are large, flattened, but deep, well-colored, and of excellent substance and texture. Yield is heavy, and canned products are of excellent quality. **Queens**, also by Schermerhorn, is a new variety similar to Rutgers but earlier.

The Comet group embraces several varieties well adapted for greenhouse and for trellis culture outdoors. Among them are **Grand Rapids Forcing, Waltham Forcing, Trellis,** and **Lloyd Forcing.** Fruits are rather small, flattened, smooth, few-celled, firm, well-colored, and uniform in their characters.

King Humbert and **San Marzano** are Italian varieties, small, oblong, and extensively grown for cannery, especially in California. They are desirable for paste, purée, soup, and for blending in juice because of meaty flesh (high percentage of solids) and fine color. The new **Redtop** by Tapley is very promising in this group, with very heavy yield, fine quality, and short picking season. The vine is short and compact.

Doublerich, bred by A. F. Yeager of New Hampshire, is marked by very high vitamin C content.

Ponderosa is a "beefsteak" tomato suitable for the home garden. Fruits are very large, rather irregular in shape, flat, pink, with much flesh and many small cells.

Mingold and **Jubilee** are well-shaped varieties of deep yellow color, much better than the old Golden Queen.

Oddities. For curiosity and fancy as well as for preserves, home gardeners like to plant such varieties as Currant, Cherry, Red and Yellow Pear, Red and Yellow Plum and Peach, the last with fuzzy skin.

Ground Cherry or **Husk Tomato,** *Physalis vulgaris,* is not a true tomato though it belongs to the family Solanaceae. The little fruits, yellow and sweet, are enclosed in a husk.

PLANT GROWING

Many plans for tomato-plant growing are successful. These programs are not separate and distinct, but methods may shade off from one to another to suit conditions. Refer to Chapter 9, "Growing Plants for Outdoor Setting."

Northern outdoor growers sometimes make their first sales of tomatoes at 25 to 30 cents a pound. Later tomatoes may sell at 50 cents or less a 20-pound basket. That is an important difference.

To be able to sell early tomatoes at high prices, one must have excellent plants, of good size, and so grown that they will continue uninterrupted progress after they are set in the field.

A good early plant is about 10 inches tall and has a heavy, firm, dark-colored stem, with full, dark, healthy foliage and a cluster of buds or even of blossoms. It should not be hardened severely, certainly not to become old, wiry, or yellow.

A suggested plan for growing tomato plants is given on page 149. As there are about 7,500 seeds in an ounce, 2 ounces of

seed are ample for plants for an acre, although some planters sow more. With costly hybrid seed, much less will suffice.

Plants for cannery crop in the north are grown as for early market tomatoes, but the requirement for economy is served by transplanting at 1½ by 1½ inches to 2 by 2 inches. Flats are often used to facilitate hauling to the field, or plants may be transplanted to the soil of cold frames. Seedlings may be started in the greenhouse or hotbed and set to open beds where climate permits.

Open seedbed. Where the season is long or when fall settings are to be made, plants may be grown in a seedbed in open ground, requiring 4 to 6 weeks. Transplanting before field setting is not necessary if seed is not sown too thickly. Not only must this period in the seedbed be frost free, but temperature must be high enough for good germination and growth. Otherwise, seedlings had better be started in cold frame or hotbed and pricked out to the open bed.

Many northern tomatoes for cannery are grown from plants shipped from the south; see page 150.

Direct seeding.[8] Seeds of tomatoes are often sowed in the field, especially in the midwest and California, where the season is sufficiently long. This saves the labor of growing plants, but the control of insects, disease, and weeds is more difficult and costly. Some experiment-station workers commend the method, but others have reported results of experiments in field sowing which do not encourage the practice. Seed is usually drilled and thinned.

FIELD SETTING

Spacing. Tomatoes are spaced at widely ranging distances according to varieties and soils. Short-branching early varieties such as Victor may be set as closely as 2 by 3 feet. Most varieties call for 12 to 18 square feet per plant. It has been shown that close spacing increases yields with no harm to the product.

It is wise to make spacing between the rows wider than in the rows. for example, 2½ by 6 rather than 4 by 4 feet. This is desirable for weed control, for economy in spraying, and for convenience and avoidance of damage to vines in picking. Spacing 3 by 5 feet requires about 2,900 plants per acre.

For training, single stem, spacing ranges from 15 inches by 3 feet to 2 by 3½ feet.

Handsetting. For the early crop, plants may well be set by hand, the maximum amount of soil being kept about the roots. It is not much more costly than machine work, and it involves less equipment, less organization, and a smaller gang.

Hand setting may be done rapidly with a spade. One person makes a wedge-shaped hole, a second holds the plant in place, and the first steps on the soil to make close contact between root and earth. If necessary a third person may drop a cupful of water or starter solution (page 185) into the open hole; this is of greater value in making contact between soil and plant than for the actual water supplied. Roots should never be doubled back in setting.

Transplanting machines are commonly used for large plantings, especially for cannery. They are equipped to apply water or starter solution, and they may have attachments for band placement of fertilizer.

If plants are too tall, it is best to mark out a fairly deep row and lay plants lengthwise with only a 6-inch top extending above ground. Even so, such plants are clumsy to handle and they start slowly. A slow start may be serious if hot dry weather should follow, to interfere with the setting of fruit.

Sugar spray. Spraying transplants with a 10% sugar solution several days before pulling has increased survival and growth. It has been most effective when applied to (*a*) very succulent plants, (*b*) transplants that could not be planted for some time after pulling, and (*c*) transplants set in the field during extremely hot weather.

FRUIT-SET HORMONES

Tomato blossoms usually fail to set fruits well when average night temperatures are below 55° F. Certain hormone-like chemicals, notably parachlorophenoxyacetic acid (PCPA) and some others, have proved valuable to induce setting of fruit in early tomatoes. These are sold under various trade names. They are applied as a spray according to directions, care being taken to reach only the blossom cluster; otherwise leaves and stems may be damaged. Softening of fruits in greenhouses seems to

have resulted from use of these materials, but it works well outdoors.

CULTIVATION AND MULCHING

Cultivation and weeding follow standard practice. No practical chemical weed control has been proposed thus far.

Mulching tomato soil with straw or manure is valuable for conserving of moisture and keeping fruit clean and unblemished Organisms decomposing the mulch may rob the plants of nitrogen, as stated on page 172.

PRUNING AND TRAINING

Most of the tomatoes grown in New England are trained to single stem and supported. Some market gardeners in other

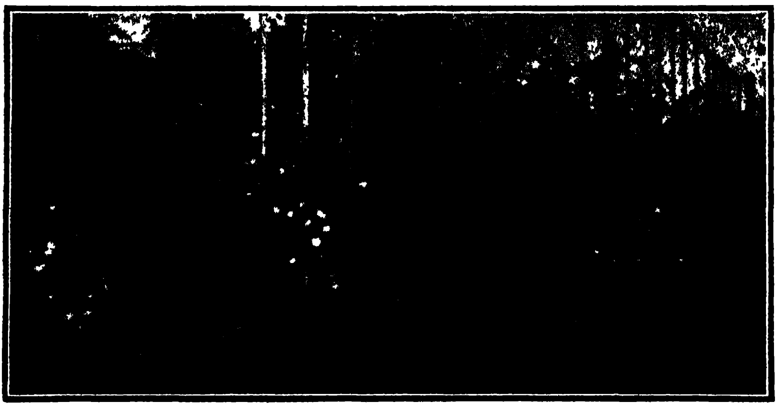

FIG. 18.2. Train tomatoes (*a*) on stakes or (*b*) on strings.

regions follow the practice, as is done in many shipping districts, but not in all. Cannery crop tomatoes are not pruned and are allowed to run freely on the ground. On New England and some other markets trained tomatoes are quoted separately as "trellis" tomatoes and at a higher price than others.

Two plans of training are followed. One calls for a stake 5 or 6 feet long driven into the ground beside each plant. Plants are tied to the stake every 12 inches or so.

Under the New England trellis system, heavy posts, well anchored, are set at the ends of the rows, with lighter posts be-

tween. Heavy wire, 10 or 12 gauge, is strung on top of the posts at a height of 5 or 6 feet. Binder twine or cheap jute string is tied near the base of the plant, with a bowline or other non-slip knot, and then to the wire. The plants are merely twisted around the string, no tying being necessary.

In both methods, plants are pruned to single stem by breaking out the branches from the nodes while they are small. If mosaic is troublesome, a knife should not be used as it will carry infection; nor should the broken surface be touched by the fingers.

There is no single answer to the question "to train or not to train." Not all the arguments pro or con have equal weight, and some may have no weight in a given situation. Experimental results, of which many are published, do not agree, partly because comparisons were on different bases and spacing systems differed widely.[8]

Advantages of Training

1. Earlier yield, due primarily to more plants per acre and so more first clusters.
2. High yield per acre. Yield per plant is reduced, but the larger number of plants per acre under training may equalize or increase the yield per acre.
3. Easier cultivating and spraying.
4. Finer quality of fruit—smoother, cleaner, and more even in size and color.
5. Less injury from snails, wireworms, and decay infection from the soil.
6. Easier and more rapid picking.
7. Harvest finished earlier, avoiding the marketing of inferior, late fruits on a low-price market.

Disadvantages of Training

1. Much higher cost per acre in plants, materials, and labor for training.
2. More blossom-end rot. Thompson has found that root systems of pruned plants are restricted as well as tops, which would tend to reduce the capacity of the plant to use the water of the soil. This in turn would favor blossom-end rot, which is caused by water deficit.

IRRIGATION

The great majority of tomatoes are grown without benefit of irrigation. The tomato withstands drouth fairly well, especially on heavier or high-humus soils. On the other hand, irrigation hastens maturity for early market, especially in the event of early drouth, and it may serve to lengthen the picking season and increase the yield. A steady moisture supply is desirable to prevent growth cracks in fruit.

In arid and semi-arid regions, water generally is applied in furrows between rows. The first watering, soon after setting may be in a furrow close to the plants. Then a furrow is thrown toward the row before the second irrigation. Too much water after transplanting and before the first fruits are set may result in overgrowth of vines or dropping of fruit. Thorough watering just before the harvest begins with rather sparse watering thereafter is good practice. If the soil becomes too dry, irrigation or rains may cause excessive cracking.

DISEASES AND INSECTS

In many regions, little damage is done to tomatoes by insects and diseases. At the same time, the total number of enemies encountered in various regions is large. The principal counter measures are seed treatment for damping-off, the application of copper or carbamate dust or spray in plant bed and field for leaf diseases, and the selection of strains resistant to fusarium.

Diseases

Fusarium wilt, caused by *Fusarium lycopersici,* prevails in all but the more northerly states but is more troublesome east of the Mississippi than west. It remains in the soil for years. It invades the plant through the roots, clogs the conducting channels, and so causes wilting, yellowing, reduction of yield, and the death of plants. Spraying and dusting are of no service since the fungus is deep within the plant. The only effective controls are long-time rotation and use of resistant strains, of which many are now available.

Leaf spots, caused by *Alternaria solani* and *Septoria lycopersici,* are troublesome over wide areas of the country. They

destroy foliage and reduce the crop, besides rendering the fruits more liable to sunscald. Both fungi winter in refuse or weeds of related species and may be seed borne. A macrosporium causes the nailhead spot of market tomatoes. Rotation, seed treatment, and carbamate or copper spray or dust in plant bed and field are control measures. Some newer strains are partially resistant.

The late blight of potatoes, caused by *Phytophthora infestans*, also affects tomatoes. Infection often occurs in the plant bed, and stem lesions may kill or cripple the plants soon after field setting. Late blight also causes a serious fruit rot. Treatment as for other leaf diseases is usually effective. Copper sprays or dusts have been more effective than carbamates.

Bacterial canker, caused by *Corynebacterium michiganense,** appears as wilting, rolling, and yellowing of leaves on one branch or one side of a plant and pale streaks on the stem. It also causes small spots on fruits. Use of seed from disease-free plants, careful plowing under of refuse, rotation, and seed treatment are recommended. Freedom from the disease is a requirement for seed certification in some states.

Verticillium wilt, caused by *Verticillium albo-atrum,* appears as a yellowing of leaves in the center of the plant. Rotation helps, but no completely satisfactory control is known.

Western blight, yellows, curly top—cause unknown—is a serious enemy in California and other western states. The leaves roll, become thickened and brittle, with purple veins and yellow surface. The disease is probably a virus related to curly top of beets, and leaf hoppers seem to effect its spread. Hot weather aggravates it. There is no effective control, but the work of developing resistant strains is in progress.

Spotted wilt is another virus disease characterized by sunken blotchy areas and prevalent when tomato plants and infected flower plants are grown together.

Mosaic is not associated with any known organism. It assumes various forms: dwarfing, patchy discoloration of leaves, threadlike leaves or "shoestrings," and sometimes dark streaks on the stem. The disease winters on many weeds, in roots as well

* Naming of bacterial disease organisms is under revision; hence literature varies in the use of genus names, *Bacterium, Corynebacterium, Erwinea, Phytomonas, Pseudomonas,* and *Xanthomonas.*

as tops, and will persist in the soil for a while. It is carried by hands of workers bearing tobacco mosaic virus and by aphids and other sucking insects. Control is by eliminating host weeds or crops, especially near plant beds, by controlling aphids, and by avoiding the use of knives in pruning.

Gray wall, brown wall, internal browning are terms often used interchangeably for an increasingly important tomato disorder. Fruits do not ripen properly and have large gray-green blotchy areas. The fruit wall under these areas is often brown and corky. Holmes of the Rockefeller Institute for Medical Research attributes the trouble to a strain of tobacco mosaic virus carried over winter in the weed plantain. Avoiding plantain-infested fields has helped control this disease.

Damping-off is caused by various fungi. See page 242.

Market diseases. See "Market Diseases of Tomatoes."[13]

Blossom-end rot is a physiological trouble related to irregularity in moisture supply and loss. Mold or decay organisms usually follow. There may be ample water in the soil, but, if the supply is not adequate at the blossom end of the fruit, tissue breaks down and dies. In poorly drained soil, there is not sufficient aeration for good root development and plants may not be able to take up enough water for their needs, even though ample moisture is present. Control involves any measure that will insure a steady water supply: irrigation, drainage, and building up organic matter. Some varieties seem more susceptible than others.

Puffiness is not a disease, but the term refers to hollow spaces within the tomato, between the jellylike placental matrix and

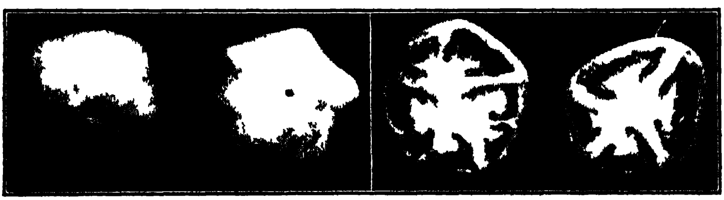

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FIG. 183. Puffiness in tomatoes. See text.

the outer wall, and affected fruits tend to be somewhat angular in form. Its causes are not fully understood, but heredity or variety is a factor, as is poor pollination. It seems more com-

mon in round than in flat varieties and is more prevalent in fruits that are picked green. There is evidence that high moisture and high temperature favor puffing, especially if they occur early in the development of the fruit. Fertilizer treatments have been found helpful in some situations. Plants treated with fruit-set hormones sometimes produce puffy fruits.

Insects

Green tomato worm or **horn worm,** *Protoparce sexta,* is half an inch in diameter and 3 inches long, with a single horn on the tail. The worms have a great capacity for tomato foliage. Usually hand picking will control them. as they are not hard to find when skeletonized leaves are spotted. Parathion spray or dust may be used if they become serious.

Fruit worm, *Heliothis obsoleta,* is the same as the cotton boll worm and the corn ear worm. Damage is most prevalent in the south. Holes are eaten in the fruits. Arsenical in Bordeaux or rotenone dust will usually control.

Cutworms, family Noctuidae, winter in the soil and emerge to cut off newly set plants. They are more serious where sod has been plowed under. Chlordane, 5% dust, may be used, or a spoonful of poison bran mash may be placed as a bait near each plant. (See page 456.)

Flea beetles, family Chrysomelidae, are little black jumping beetles that perforate leaves, especially of newly set plants. Bordeaux with arsenical serves as a repellent. One application of DDT just before field setting is suggested. If later treatment is necessary, use rotenone.

HARVESTING AND MARKETING

Judging maturity. Most tomatoes for shipment are picked at mature green stage when they have reached full size but have not begun to show red. They ripen readily after harvest and develop good quality if well handled. Immature green tomatoes do not ripen well. No hard and fast rule clearly separates these two maturity stages. Experience is the best teacher. If mature green tomatoes are cut in two, the pulp that fills the cells is jellylike. Seeds are dragged aside by the knife and not cut through. In immature green tomatoes, seeds are easily cut

and the jellylike consistency of the pulp is undeveloped. This test ruins the tomato, but it serves to check one's judgment until experience is gained. One learns, however, to recognize a heightened gloss, less hairiness, and a more whitish green as tomatoes reach the mature green stage. The darkening of the "eye," or the ring where the stem parts from the fruit, is an unreliable guide. The various stages of ripening after mature green may be designated as turning, pink or half ripe, ripe and firm, and ripe and soft. The first two, and sometimes the third, are best for near-by marketing.

Picking at turning or pink stage for shipment to distant markets is being explored in the hope of improving the frequently abominable quality of "repacks" offered at retail. One obstacle is the increased cost of more frequent pickings. This plan is more exacting in its requirements as to refrigeration and speed in transit.

For processing, tomatoes are picked at a fully ripe stage. Cracking is a serious problem since molds and rots find ready entrance to reduce the quality of the fruit and the picked product. Pickers must be well-trained and carefully supervised to maintain a high percentage of U. S. No. 1, since most cannery buying is on grade.

Picking. Various kinds of picking containers are common. When baskets are the market package, they may make one trip to the field for picking, or used baskets may be procured for the purpose. Special picking baskets or boxes, strong, of smooth inside surface to avoid damage to the fruits, and not too deep, are generally considered better. The half-bushel size is good.

In picking, take care to avoid unnecessary trampling of vines. Remove the stem of the fruit as it is picked so that other fruits will not be punctured. Avoid bruising or squeezing the fruits.

Cost of picking may be materially reduced by means of improved methods. Some use has been made of conveyor-booms which receive tomatoes from the pickers and deliver them to containers on a truck.

Sorting or grading. The first sorting occurs as the fruits are picked. Usually tomatoes for shipment are graded to U. S. No. 1, or better, representing a standard quality of high utility that will admit a large share of a well-grown crop. It is not a de luxe grade suited only for fanciest trade.

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FIG 184 A simple set-up for packing tomatoes speedily and well (a) Boys at left are sorting tomatoes into three sizes under 2¼ inches, 2¾ to 3¼ inches, and over 3¼ inches These sizes may be varied to fit the tomatoes at hand

(b) Side view showing packing stands with tray for paper wraps and lug box, held in slanting position for packing The outfit is inexpensive and portable. Two persons or even one can use it to advantage

Packages. The lug box, approximately $6\frac{7}{16}$ by $13\frac{1}{2}$ by 16 inches, carrying 30 pounds net, is the most widely adopted package for tomatoes, almost to the exclusion of others for shipping The fruit is packed in layers, and an inch or more of bulge is usual. Extra cleats on the cover serve to protect the upper tomatoes. See Fig 18.6. An increasing share of tomatoes for repacking are handled jumble-packed in returnable field boxes.

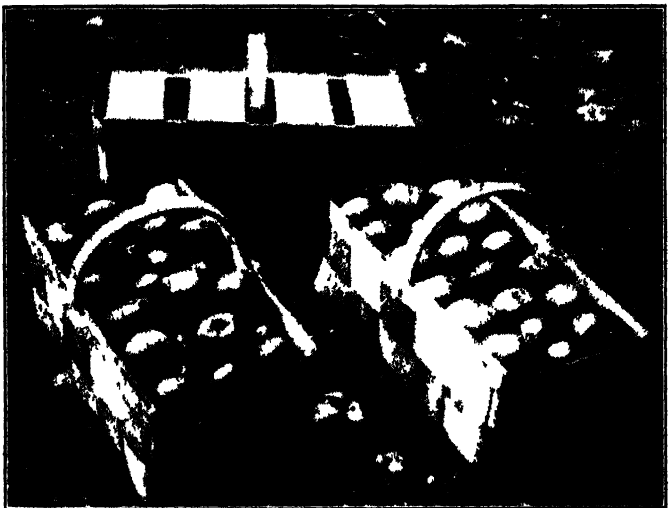

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FIG. 18.5 A good finish makes a pack more attractive.

The square braid basket in 8- and 12-quart sizes is widely used on local markets. The bushel basket and the Jersey $\frac{5}{8}$-bushel basket are deeper than is desirable for market purposes although they are common in some places. Hothouse tomatoes are usually packed without overfilling, 8 pounds in an 8-quart corrugated board basket. Repacked tomatoes are handled in cellophane window cartons or tubes carrying 4 or 5 fruits. These are packed 10 in a corrugated board carton.

Set-up for sorting and packing. On a small scale, sorting for grade may be done at a table, No. 1's and No. 2's being put in their proper baskets, and off-grades being discarded. On a larger scale, moving belts help greatly.

The packing of lug boxes with definite rows and layers calls for rather careful sizing of fruit. The packed boxes are marked

6 by 6, 6 by 7, or 7 by 7, according to the number of tomatoes, each way, in each of three layers. For small tomatoes, U. S. Standards permit "double wrap," two tomatoes in one paper, and "bridge pack," a partial additional layer. Three suitable size ranges for a starting point are 1¾–2¼, 2¼–2¾, and 2¾–3¼ inches in diameter. The larger sizes are difficult to pack. Sizing cards enable the worker to check his sorting.

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Fig 18.6 The lug box is the principal tomato package Dealers said they could have had 15 to 20 cents more for their tomatoes if they had been in new boxes.

Packing lug boxes efficiently is a skilled occupation, readily learned but requiring long practice for the development of skill and speed Expert crews move from Florida to the north as the season advances. Workers often wrap and pack 70 tomatoes per minute in routine work Paper wraps are almost universally used for the lug-box pack. They contribute to appearance and afford cushioning between fruits. Lug boxes are lidded by hand or with a special nailing press.

For basket packing for local market, it is not necessary to size so accurately as for box packing. It is well to pack two or three layers in 8- or 12-quart baskets, using larger fruits to balance smaller ones, and bringing the pack out to an even finish. This method of packing does not take much more time than loose or jumble pack. Of course, field pack is cheaper, but results are poorer. Most well-managed packing set-ups achieve economy as well as a good pack. See Fig. 18.5.

Loading. Lug boxes are loaded with the length of the box crosswise of the car. Wooden strips are nailed on the boxes, butting closely against the sides of the car, and so holding the

load in place. If the stacks of boxes do not come out even, "gate bracing" is set up to fill the extra space.

Ripening.[12] When green-wrap tomatoes reach market they go to merchants who unpack them, sorting out those that have ripened sufficiently to sell. Green fruits are put in tight rooms for ripening at a temperature of about 70° F. with sufficiently high humidity to prevent wilting and shriveling.

Northern growers and home gardeners sometimes pick mature green tomatoes in the fall and allow them to ripen after frost has killed the plants.

TOMATO FORCING

The tomato is the leading commercial greenhouse vegetable crop.[3] Ranges of glass up to 10 or even 20 acres are devoted chiefly to its culture. Tomatoes may be grown in plant houses after plants have gone out to frames. A fall crop may also be grown, but yields are low under the short days of autumn. Culture of tomatoes in midwinter is difficult and costly.

Greenhouse tomatoes are grown to single stem, training on twine about as in the field. Temperatures are kept at about 75° F. by day and 5 or 10° lower at night. Higher temperatures with the sun shining do no harm. Ventilation is primarily a matter of temperature and humidity control; too high humidity favors leaf mold (causative agent, *Cladosporium fulvum*). Plants need to be jarred or tapped daily to insure proper pollination of fruits. Leading forcing varieties are Globe, Comet, Grand Rapids Forcing, Trellis 22, and Waltham Forcing.

A nematode or eelworm, *Heterodera radicicola,* a minute worm, infests tomato and cucumber plants and greenhouse soil, causing root knot and interfering with intake of water. The pest is usually controlled by steam or hot water sterilization.

CONCERNING TOMATOES

Food value and use

The tomato is one of the most highly praised of human foods. It is beautiful to look upon, and most people eat it with great relish, cooked, in salad, or out of hand. It is our greatest cannery vegetable, packed whole (or not so whole), or as juice, as soup,

or as ketchup, and it enters into various other condiments. Paste and purée are concentrated forms.

Tomato juice has become an exceedingly popular appetizer and beverage, climbing from less than 2 million cases * in 1930 to nearly 36 million in 1951. The per capita consumption in 1952 was 5.1 lbs. of tomato juice. The quality of the product has been greatly improved, and the solids are now kept well in suspension.

Though the tomato consists largely of water, it has high nutritive value, being a good source of vitamins A and B_1 (thiamin) and an excellent source of vitamin C (ascorbic acid). Ascorbic acid is more commonly deficient in the diet than vitamin A or B, and tomatoes and citrus fruit are looked to as the most dependable sources. Ascorbic acid is not seriously harmed by properly managed cooking and canning. The low cost during the local season of harvest and when canned makes the tomato one of our most useful vegetables.

The cookery and serving of the tomato are simple. The fresh vine-ripened fruit is delicious when served raw, with no more than a salt shaker at hand. Tomato salads may be dressed to please the taste. In cookery, 10 to 20 minutes' stewing is the commonest preparation. Tomatoes are baked, escalloped, and used in countless dishes with rice, cheese, and macaroni.

Botany

The tomato is one of the most plastic of vegetable plants. It responds readily to a wide variety of conditions, lagging in growth but still surviving under drouth or starvation, only to respond speedily when its needs are supplied. Its leaves and stems readily reflect, in color and form, symptoms of various deficiencies. It may be grown on peat or mineral soil, on quartz sand, or in culture solution. The tomato rivals the potato, or perhaps exceeds it, as a subject of research, not only for its own sake but as a "guinea pig" to yield new knowledge to be applied to plants in general. See Chapter 7 for a discussion of vegetation and reproduction in the tomato.

* Cases of canned goods represent 24 cans of No. 2 size, about 20 ounces, 12 cans of No. 5 size, or 6 cans of No. 10 size. A case of each of these sizes and of others represents roughly the same quantity of goods.

The tomato, *Lycopersicum esculentum* (*lycos*, wolf; *persica*, peach; *esculentum*, edible), family Solanaceae, is related to the potato; see page 306 for a list of other cousins. It is an herbaceous annual plant. A greenhouse plant some years ago grew for 18 months and attained a length of 40 feet.

The root system is wide and deep but without extended tap root. The stem is angular, hairy, and glandular, secreting a rank-smelling greenish yellow juice.

Some varieties are called "determinate" or, perhaps better, "short-branching" in habit; this probably means that internodes are short, but the true meaning of determinate is that the axis ends in a flower cluster.

Flower clusters occur along the stem, and not at the nodes or leaf axils as in most plants.

Pollination is mostly by selfing, neither wind nor insects being important. Cross pollination to the extent of 1 or 2% has been demonstrated, and one worker found as much as 15%. Smith[14] has found that pollen grains germinate best at 85° F., nearly as well at 70° F., poorly at 50° F., and very poorly at 100° F. Thus both high and low temperatures interfere with the set of fruit.

The fruit is a true berry, more truly than the raspberry, which is an aggregate fruit. In most varieties, fertilization of ovules (seeds) is necessary for development of the fruit, though some varieties are more or less parthenocarpic.*

Breeding

The little wild cherry or currant tomato and the rough primitive large tomato have been developed to the shapely fruits of present-day markets by means of endless selection and crossing and recrossing, the refinements of the best cultivated varieties being combined with the vigor and disease resistance of aboriginal stocks. Form, color, fleshiness, and smoothness have been sought in fruit along with rugged vine and heavy yield. Other quests are for higher ascorbic acid content, resistance to cracking, and concentration of maturity.

Prevalence of fusarium initiated a wave of breeding for resistance, led by Essary of Tennessee, Edgerton of Louisiana,

* *Parthenos*, virgin; *karpos*, fruit. Developing fruit without fertilization of ovules.

Norton of Maryland, and Pritchard of Washington. Pritchard used a French tomato, Marvel, as a resistant parent and made crosses with other varieties, yielding Marglobe and Pritchard as well as many others of lesser importance. More recent work has been carried forward with fuller application of genetic principles. Yeager of North Dakota (now of New Hampshire) worked for varieties suitable for rigorous northern climates.

The prevalence of Western yellows, carried by leafhoppers, has been the occasion of much effort to breed resistant strains.

Mode of inheritance has been studied by MacArthur, Lindstrom, and others; cytological studies have been carried on, as well as work on mutations and polyploidy The normal chromosome number (n) is 12.

Wellington in 1912 and 1922 demonstrated heterosis or hybrid vigor. See Boswell [5] for references.

A number of hybrid varieties are on the market, but the gain in vigor is not as striking as with sweet corn. Also, the techniques of producing hybrid seed are more difficult and costly. Larson [6] and Rick [7] have developed male-sterile strains which help. Hybrid seed is costly, but careful plant growing insures a higher percentage of good plants per 1,000 seeds.

Seed production

Seed is saved by crushing fruits and fermenting them in a crock, barrel, or vat for a long enough time for the jellylike pulp to disintegrate. The time required depends upon temperature; it is ordinarily a day or so. Large producers omit fermentation. Seed is then washed, dried, and stored. Germination is vigorous and persists for many years, generally at least five or six, under good storage conditions, and sometimes even ten to twelve.

Importance

The tomato is the second most important vegetable crop, following the Irish potato. It is grown for home and market in every state of the Union. For fresh market production the leading states are California, Texas, Florida, New Jersey, and New York; for cannery, California, Indiana, Maryland, New Jersey, and Ohio.

The cannery crop is grown on about 425,000 acres (10-year average) and the market crop on about 230,000 acres, but the

cannery crop brings farmers $90,000,000 against $110,000,000 for fresh tomatoes. See tables in *Agricultural Statistics*, issued annually by the U. S. Department of Agriculture, for full data.

Yields and costs

For cannery the average yield for the United States, 10-year average, is 6.2 tons per acre, in some states over 10 tons, in others as low as 2 tons. Good growers reach yields of 15 tons per acre and even more, but membership in a "Ten Ton Club" is an honor in many states. The average price for 1931-1940 was $12.02 per ton, but for 1951 it had risen to $31.40, and in some states it went above $40.00.

For fresh market, the average yield is 150 bushels per acre, the range being from 70 bushels or lower to more than 300 bushels.

TABLE 18.1. AVERAGE COST PER ACRE, CANNING FACTORY TOMATOES

Data for 24 farms (better than average) in New York, 1951

Costs for growing:	
Land	$ 9.73
Labor (29.5 man-hours)	30.78
Tractor	14.40
Other equipment	12.95
Fertilizer	38.37
Spray and dust	12.30
Plants	38.37
Other	12.61
	$169.51
Costs for harvesting and selling:	
Labor (118.5 man-hours)	$166.73
Truck	4.85
Hired hauling	6.61
Other	15.44
	$193.63
Total	$363.14
Average yield per acre, 24 farms	18.6 tons
Average cost per ton	$19.48
Average return per ton	$31.55

C. D. Kearl, *Cornell Agr. Econ. Mimeo* 793.

Farm prices in early states have averaged about $4.50 a bushel; the average price in intermediate and late states is about $3.00.

Many studies have been made of the costs of producing cannery tomatoes. Table 18.1 shows a cost analysis for cannery tomatoes on 24 farms in New York. Costs for producing for fresh market vary widely, being high in south Florida and low in north Texas. Costs for trellis tomatoes in New England may exceed $600 per acre, but yields reach 1,500 bushels per acre.

History

Not until the western world had been opened to Europeans did the tomato become a world-wide food. It was mentioned in the herbal * of Matthiolus in 1554, which said it had but lately been brought to Italy. In 1596, Gerarde reported growing the tomato in his garden in England. He reported its use abroad, cooked with salt, pepper, and oil, and also used as a sauce. But Gerarde did not think much of tomatoes, for he says, "They yield very little nourishment to the bodie and the same naught and corrupt." Ideas about the tomato have changed!

The tomato was known as "gold apple" and "love apple" in various languages, *pomi d'oro* and now *pomidoro* in Italian, and *pomme d'amour* in French. The word tomato, not used until 1695, is said to be derived from the Aztec "Xitomate" or "Xito tomate." Webster prefers the pronunciation to-may'to, although to-mah'to and even to-mat'to are still used, especially in the northeast.

Food use of the tomato began early in its history, but, until about a hundred years ago, some thought it actually poisonous or disposing to cancer. It was not until about 1830 that it found a place in our markets.

* Herbals are old books of botany, listing, describing, and illustrating plants of many lands. Many of them are large and comprehensive. They were first published three or four hundred years ago, soon after the invention of printing. They were a natural outgrowth of the wave of exploration following the day of Columbus. The interest of their writers centered around the medicinal use of plants. Naturally their botany was primitive, according to modern standards, but the books are valuable sources on the history of plants and of new ideas about plants. Among the better known are those of Gerarde, Matthiolus, Quintinye, Parkinson, Dodoens, Camerarius, and Tournefort. Herbals may be seen in large city, university, and botanical libraries, where they are treasured antiques.

Wild forms. Several wild forms of tomatoes are known, of which one is the Cherry tomato, *Lycopersicum cerasiforme,* found as far north as Texas and California. Another resembles more closely our cultivated tomatoes, having large but misshapen fruits. It is likely that our modern tomatoes combine some of the characters of both. Some primitive forms, notably *L. pimpinellifolium,* have been very useful in modern breeding, especially for disease resistance.

PEPPERS AND EGGPLANTS

Peppers and eggplants belong to the same family as tomato and have much in common in adaptation and management. Both are sensitive to frost and require warm weather for good growth, although some of the newer varieties do well in northern climates. Soil management may be planned much as for tomatoes. Peppers are rather sensitive to soil and weather conditions affecting set of fruit.

Varieties of sweet peppers include:

Pennwonder is a good early variety, and **Vinedale** appears promising.

Allbig, formerly Illinois F5, is early, of good size, long, pointed, and very prolific.

California Wonder, a late variety with large plant and handsome thick-fleshed fruits. Improved strains are earlier and more prolific.

Worldbeater is earlier and more prolific than California Wonder, but with less regular form and thinner walls. **Burlington** is an improvement.

Pimento is late, heart shaped, and thick fleshed; it is widely used for canning.

There are many pungent or "hot" varieties such as **Tabasco, Cayenne, Chili, Hungarian Yellow Wax,** and **Red Cherry.**

A leading northern variety of eggplant is **Black Beauty. New Hampshire** and **Black Magic,** a hybrid, have been bred for northern climates **Florida Highbush** and **Fort Myers Market** are grown in the south for shipment to the north.

Plants of peppers and eggplants are grown about like tomatoes, though spacing in plant bed and in the field is closer.

Local advice may be followed in the control of diseases. Several of those affecting peppers are similar in cause and control to tomato diseases. Wilt of eggplant, caused by the fungus *Verticillium,* is seed borne and harbors in the soil. Clean seed

and long rotation are recommended controls. *Phomopsis* attacks leaves, stems, and fruits.

Sweet peppers are usually harvested when they have reached full size and are still green. Some are marketed when red-ripe. Hot peppers are picked either fresh or fully mature.

Eggplants are usable as early as one chooses to pick them and until full size is reached. They tend to become pulpy when overmature.

Both peppers and eggplants are marketed locally and at a distance in baskets or boxes. A 1⅗-bushel crate is used in Florida. Eggplants are often wrapped with thin paper. Neither is suitable for fresh storage for any considerable time, although peppers are often dried, especially the hot varieties.

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See references in Chapter 7 on vegetation and reproduction.

19

Sweet Corn

Sweet corn originated in the Americas and has largely remained on this side of the ocean. Field corn is important in some other parts of the world, but sweet corn is not. One of the wonders of travel in America, when cultured Europeans come and see us, is the sight of aristocratic diners in an elite hotel munching the kernels from buttered ears of sweet corn.

Sweet corn grows in every corner of the country, and it is a cherished American delicacy, in spite of the fact that probably half of the population have never tasted a really good ear, for sweet corn declines in quality very rapidly after it is snapped from the parent stalk.

Sweet corn is equally adapted for home garden or commercial production. It is one of the four major processing vegetables. Freezing and drying are good methods of preserving.

ADAPTATION

Sweet corn is a relatively easy crop to grow, and it is not difficult to have a good succession in the home garden. So many general farmers plant it to sell that it becomes very cheap on most markets at certain seasons. The processing crop is contracted for at low prices, and the average yield, country wide, is only about 2½ tons per acre, in the husk. One who expects to receive good prices for fresh sweet corn must market early or late in the season or offer an article which is of prime quality at the time the housewife gets it. It is an excellent crop for roadside marketing. Many growers now harvest sweet corn in the cool of the dawn, deliver it to city stores by ten o'clock, and are well paid for it. But the vast bulk of the sweet corn produced brings low prices to the farmers, often as low as two cents an ear.

Climate. Sweet corn is not hardy to frost but is somewhat less sensitive to cold than the tomato or bean, partly because the growing point in the seedling is below soil and may escape when leaf blades are injured. Different varieties require from

Cornell Seed Company

Fig. 19.1. A field producing hybrid seed of Golden Cross. Note three detasseled rows of Purdue 39 to each single row of Purdue 51.

Cornell University

Insert: Inbred parents and hybrid progeny as used in most sweet-corn seed production. Left, Purdue 51, male parent; right, Purdue 39, female parent; center, Golden Cross, hybrid. Note low vigor of parents, high vigor of progeny. This illustrates heterosis or hybrid vigor.

60 to 90 or 100 days from seed to maturity. Sweet corn thrives in warm sunny weather but is more like the flint than the dent corns in its tolerance of cool conditions. It might be classed as intermediate among crops in sensitiveness to drouth. Much of the processing sweet corn is grown in northerly regions since temperatures are lower at harvest time and a short delay in harvesting or processing is not so devastating to quality as in warmer climates.

Soil. Sweet corn is grown on all sorts of soils and does well at a wide range of soil reaction, say *p*H 5.2–6.7.

Ravages of insects, especially corn ear worm and European corn borer, present a serious limiting factor in deciding whether to grow sweet corn or not and at what season to plant.

SOIL MANAGEMENT

Sweet corn can be produced on soils of only moderate fertility, but the plant responds generously to liberal supplies of organic matter and nutrients. Stable manure gives excellent results. If liberal applications, 12 to 20 tons per acre, are made, phosphorus, at the rate of about 18 pounds of phosphoric acid per ton of manure, may be the only further addition required. Without manure, 10 to 50 pounds of nitrogen and potash and 20 to 100 pounds of phosphoric acid are suggested, according to the type of soil and local recommendations and experience. The smaller applications will be made when good soil is used for the processing crop or when some factor other than fertility limits yields. On lighter or poorer soils or for intensive culture, heavier applications are appropriate. Band placement is highly desirable where maximum return must be realized from minimum applications, that is, say, 200 or 300 pounds per acre of a 5–10–5. On lighter soils side dressing once or twice with nitrogen is desirable at the rate of 50 to 100 pounds per acre of ammonium nitrate or the equivalent. This should be done well before tasseling, perhaps when the plants are knee high.

VARIETIES

Sweet-corn varieties are now largely high-quality yellow hybrids from inbred parents, commonly known simply as hybrids, although the first-generation (F_1) progeny of any cross is really a hybrid. Hybrids from inbreds are available to replace almost all old standard varieties. See page 103. Hybrids in general are superior in yield and in uniformity of growth, maturity, and ear characters.

Ideal. A good variety of sweet corn should show:

1. A vigorous growth of plant, standing well against wind storms. In late varieties tonnage of fodder for feeding may be a consideration.

2. Uniform maturity at the desired season.
3. Ears of good size, of 12 rows or more, well filled at tip and butt, well covered at the tip.
4. Deep yellow kernels, with tender pericarp.
5. High sugar content and creamy consistency.
6. Resistance to ear worm and bacterial wilt.

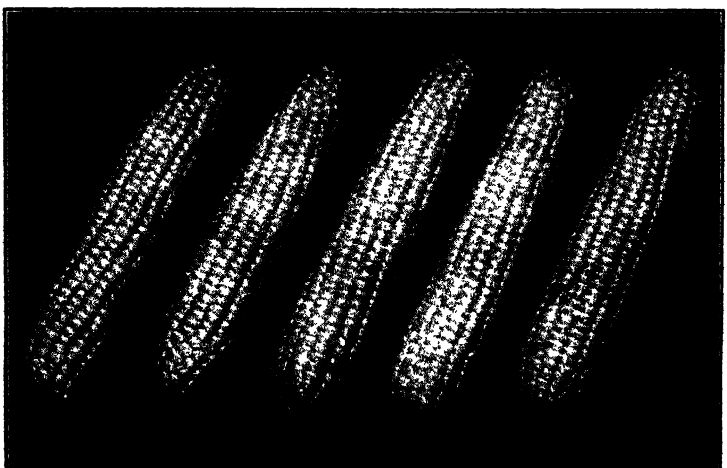
Naming should be based on *type* rather than *origin*. Thus Golden Cross is grown from inbreds out of Golden Bantam but is not of Golden Bantam type, so that Golden Cross, rather than Golden Cross Bantam, is a good name for it.

The number of sweet-corn varieties and strains is legion. The following brief list includes the most important ones, with which others can be compared. They are hybrids unless otherwise indicated. Variety names and trade names are badly confused.

Seneca 60, North Star, and **Spancross** are early (60 to 65 days); ears are yellow, 8- to 12-rowed, productive, and uniform in maturity. **North Star** is marked by good come-up early in the season.

Marcross and **Carmelcross** are the leading second early home and market varieties (70 to 75 days), ears yellow, 12 to 14 rows, taller and more productive than the first earlies.

Golden Cross is the leading variety of sweet corn. It grows strongly and vigorously, maturing in 80 to 85 days. Ears are 10- to 14-rowed, with



Associated Seed Growers, Inc.

FIG. 192. Golden Cross is the leading variety of sweet corn. It deserves its place by reason of well-shaped and well-filled ears, high table quality, and heavy yield.

kernels of medium depth and breadth, creamy yellow in color, with moderately tender seed coats, and excellent table quality. See page 365. There are many other strains, many under distinct variety names, that differ in details of type and in adaptation. **Aristogold** is popular in the south. **Iochief** is of fine quality but is hard to pull. **Seneca Chief** is of exceptional table quality.

Golden Country Gentleman or **Golden Colonel** is a shoe-peg variety for canning.

PLANTING

Soil preparation for sweet corn is not as exacting as for small seeds, but cloddy soil results in uneven germination and a poor stand, especially if rains are not timely.

When to plant. Accepting some risk of frost injury, it is not uncommon to plant early sweet corn soon after the average date of last killing frost. Plantings made ten days to two weeks after that date are reasonably safe, as germination requires about a week.

A succession may be gained by planting three or more varieties at the same time, including an early, a midseason, and a main crop or late sort, following with later plantings of main crop sorts. If a planting for late maturity fails, a midseason variety may be used for the last sowing. It is better to make succession plantings when the previous sowing is up to a height of 2 to 4 inches than to go by calendar intervals of 5 to 8 days. Otherwise two plantings may mature at about the same time, especially if the first encounters cold wet weather.

Drills or hills. Planting is nowadays usually in drills rather than in hills to avoid crowding of individual plants and, presumably, to yield a larger percentage of good marketable ears. Hill planting is expedient only when the land is weedy and cross cultivation is desirable.

Spacing. Rows are usually 30 to 42 inches apart, earlier and small-growing varieties being planted closer together. Stand in the row should average 10 or 14 inches apart for most sorts, up to 16 inches as a maximum for large late ones. This means sowing of 2 or 3 seeds per foot if thinning is to be practiced. Closer spacing tends toward a larger proportion of short or irregular ears but generally higher tonnage per acre. Hills are usually spaced 3 or 3½ by 3 feet; 3 or 4 seeds are sowed per hill and the hill may be thinned to 2 or 3 stalks.

From 6 to 12 pounds of seed is required to plant an acre. The small size of seeds of many varieties, especially hybrids, must be taken into account in adjusting the planter. One seedsman states the average count of seed per ounce for the different varieties as a guide for planting. *Sorting of seed* into two or three sizes before planting is a desirable practice for sweet corn, contributing to evenness of stand and uniform maturity. See page 209.

Sweet corn is planted with a grain drill with one shoe in four or five open, the others closed, or with special corn, pea, and bean planters; with garden drills; with walking-stick planters; and by hand. Covering should be ¾ to 1 inch for early plantings or in moist or heavy soil and up to 1½ or 2 inches if soil is dry. Germination of corn is relatively strong and vigorous.

Thinning is costly, and it may be avoided after the soil is warm by testing the seed and adjusting the planter with care. Most home and even some commercial gardeners plant corn much too thick.

In the home garden it is better to plant three short rows at a time rather than one long row. This favors good pollination and well-filled ears.

Later care. *Cultivate* only to control weeds, and let cultivation be shallow. Ridging has little to commend it unless furrow irrigation is to be practiced or there is a drainage problem. There seems little reason for the common advice to cultivate deeply at first. It takes more power; it hastens drying out of the soil; and the loosening of soil is of no advantage if the land has been properly prepared. Early cultivations, even after corn is up, may be made cheaply and effectively, several rows at a time, by means of a spike-tooth harrow (see Fig. 6.4), a rotary hoe (Fig. 12.9), or a spring-tooth weeder (Fig. 12.10). Damage to plants is almost negligible and is further reduced if the work is done when plants are slightly wilted in the middle of the day.

Use of 2,4-D is now accepted practice for weed control.[11]

Hand hoeing should be unnecessary in commercial practice, but it may be required in wet seasons.

Suckering of sweet corn is likely to cost between $6 and $10 per acre. Thompson[7] has shown that the practice does not increase the yield or the proportion of good ears or the earliness. Late suckering is definitely harmful; although some growers

defend the practice, it is not generally advised. This is reasonable, for suckering removes foliage, which is the manufacturing part of the plant. The idea that leaves and ears compete with each other for the resources of the plant is erroneous. The leaves make the ears.

DISEASES AND INSECTS

Diseases

Bacterial wilt or Stewart's disease, caused by *Bacterium stewartii*, occasions serious damage in some years but not in others, probably on account of the mildness or the severity of the winters, which affects the hibernation of insects. The more northerly regions are not troubled. Early varieties are more susceptible than late ones, and some varieties are resistant. The disease winters in corn refuse, in insects, or in seed. It is carried by insects and develops more rapidly when wet weather follows planting. It is most destructive from Long Island and the Delaware peninsula west through parts of Iowa and Missouri. The disease appears after plants are half-grown, dwarfing the growth and whitening the leaves. A thick, yellowish juice oozes from the fibrovascular bundles of cut stalks, a reliable identification.

Control measures are not clear cut. Use of resistant varieties is probably the most effective practice. Cleaning up corn refuse, rotation, late planting, use of clean seed, controlling the corn flea beetle, and seed treatment are also helpful.

Smut, caused by *Ustilago zeae*, appears as a greatly enlarged growth of tissue containing a mass of black spores. It sometimes affects seedlings severely, and damage is more serious in hot dry seasons. Manure is a common carrier of infection. Seed treatment is of no avail. The only control measure is the gathering and destroying of the smut galls two to four times during a season, and this must be a community enterprise, continued for a period of years.

Insects

Corn ear worm, *Heliothis obsoleta*, is a serious enemy of sweet corn except in its most northerly ranges—Maine and Minnesota. The insect is the same as the cotton boll worm and the tomato

fruit worm. Eggs are laid by the moth on the silk, and the larvae feed on silk, on the tip of the ear, and on each other. They are cannibals and usually only one per ear survives—presumably the best one. The pupae winter in the soil in the south, and northern infestations are believed to result from annual migration. There are from one to four or even more generations in a season.

Good control is achieved by following local directions, spraying or dusting with DDT or parathion.

Timing of plantings according to emergence of broods helps in some areas, but freedom from worms and ruinously low prices may occur at the same time. Varieties with well-covered ear tips are less susceptible to injury.

European corn borer, *Pyrausta nubilalis,* came to the United States in 1909 and has been an unwelcome guest ever since. It operates from Chicago east and from Norfolk north, leaving West Virginia and inland Virginia relatively free. In Massachusetts and eastern New York a two-brooded race is found; elsewhere there is usually a single brood. The borer winters as a larva in old cornstalks and stubble and to some extent in pithy-stemmed weeds. Eggs are laid on the under sides of leaves, and larvae enter the stalk, working through succulent tissue, up or down. Their presence is often indicated by breaking over of the tassel. When they infest the ear, it is through the shank and cob, the larvae coming out to the kernels in any part of the ear.

Spraying or dusting with DDT or parathion affords good control. Ryania is used if stalks are to be used as fodder.

Control is aided by plowing under stubble completely in the fall, by late planting in the single-brood areas, and by planting for maturity between broods in two-brood areas.

HARVESTING

Maturity changes. Timely harvest is a major element in delivering a high-quality sweet corn to processor or consumer. Appleman [8] found that temperature is the major factor governing rate of ripening and progress of overripening, which is very rapid in warm weather. Here the van't Hoff principle (page 62) applies well. In ripening, the percentage of sugar declines

and that of other carbohydrates increases. Appleman used sugar-starch ratio as a measure of maturity. Sugar is soluble in alcohol, but starches, dextrins, hemicelluloses, and other higher carbohydrates are not. Kertesz[8c] proposed ratio of alcohol-soluble to alcohol-insoluble material as a measure of quality and maturity. These higher carbohydrates are largely responsible for the consistency of canned sweet corn, whether watery, creamy, or doughy. Decreasing moisture content of kernels is another measure of maturing. Toughness of hull or pericarp is measured with a succulometer, an instrument with points and a scale indicating pressure necessary to penetrate.

Judging maturity. Maturity of sweet corn is commonly tested by thumbnail pressure and is described by a series of terms, practically self-defining: blister; milk, which is the accepted stage for market and processing; dough; and dent. Time of silking gives a useful guide as to probable date of best maturity, if temperature thereafter is taken into account. The degree-day system (page 203) is used to some extent.

Huelsen[6] has studied the many factors that govern harvesting dates, undertaking to resolve the conflict between the grower's desire for heavy yield and the canner's desire for high quality. He proposes contract provisions designed for fairness to both parties.

Harvesting. Sweet corn is mostly pulled by hand, but mechanical harvesters have come into use for the processing crop. Pickers learn to judge maturity by appearance and feel of the ear.

Much sweet corn for fresh market is pulled too late for best quality. One grower, asked how he judges, said, "Watch for the day when it is best for the table; then wait four days." Sadly enough, many consumers judge by size of ear and fullness of kernels.

Pickers carry bags over the shoulder or bushel baskets. Sometimes a narrow, deep, one-horse sled is hauled between rows, one or more workers on each side, each taking care of two rows. Trucks are often driven right through the field to pick up sacks or baskets. Trucks or trailers are sometimes equipped with one or two trailing conveyors into which pickers toss the ears. In Florida the packing job on some farms is completed on the truck, which is really a rolling packing shed.

Marketing husked sweet corn.

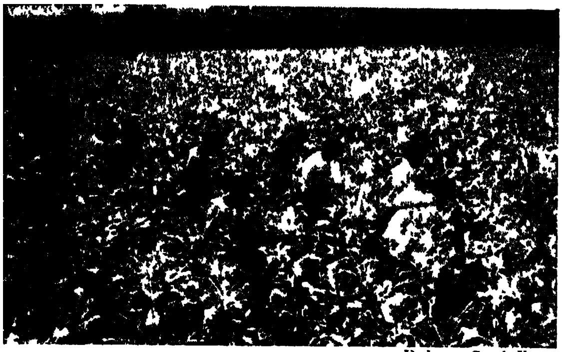


FIG 19.3 Picking

FIG. 19.4. Corn from the fields is unloaded to a roller conveyor which carries the baskets to the sorting belt.

Fig 195 Corn moves along conveyor belt where it is sorted Upper belt carries off one grade, lower the other

Fig 196 After being sorted, corn is sacked in branded bags.

Whether the corn is intended for fresh market or for processing, speedy handling from pulling to kitchen or to blanching is essential for the retention of quality. At 85° F. sweet corn loses half its sugar in 24 hours.[8] Pulling in the morning while ears are cool is an aid.

Loose or bagged corn in solid truck loads or in piles heats rapidly by respiration, as does freshly cut ensilage. If an overnight holding is necessary, a cool place is desirable. Precooling

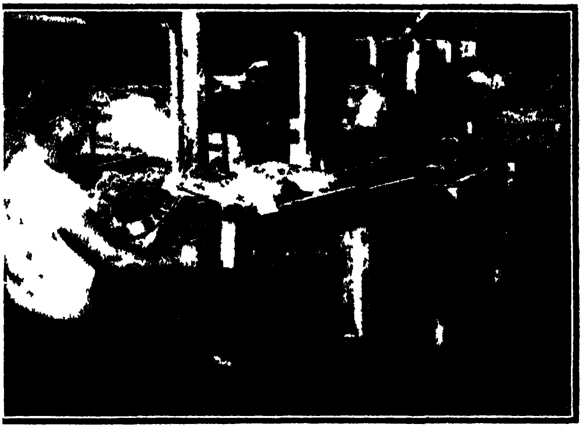


FIG. 197 Bags of corn move through ice water precooling bath.

is useful if the thermometer tells the operator that the corn has been *really* cooled to 45° F. or lower and if the low temperature is maintained. Icing between bags in the truck serves this purpose. Immersion in ice water may help but is not alone sufficient. Loose or bagged corn in solid truckloads or in piles heats rapidly by respiration, just as does freshly cut ensilage.

Usual packages for sweet corn were formerly wire-bound crates, bushel baskets, and bags carrying 50 or 60 ears, but more recently bags of 3-ply wet strength paper have come into use. They are packed with 10 to 20 pounds of cracked ice.

Paul Dickman of Florida has pioneered in the rapid handling, cooling, and prepacking of sweet corn. Picking trailers come quickly to the packing house, where ears are husked by machine, precooled by "stericooler," using chlorinated ice water, and cut to 3-inch and 5-inch lengths. They are placed 3 ears lengthwise or 5 ears crosswise on a paper tray, overwrapped with printed

transparent film, packed in cartons, and taken to a refrigerated room. Huge trucks, heavily refrigerated, take the product to northern or nearby markets.

FIG. 19.8. Corn moves into the truck where it is piled with alternating layers of crushed ice.

CONCERNING SWEET CORN

Corn is an amazing plant in many respects. The facts are stranger than fiction. It has been thoroughly studied, and every student should read the chapter in Jones and Rosa's *Truck Crop Plants* or the fascinating book by Weatherwax, *The Story of the Maize Plant*. *Singing Valleys* by Dorothy Giles is an interesting popular work on corn.

Food use

Sweet corn is used at an immature stage when kernels have reached almost full size but before the contents have passed what is called the milk stage. Calorie value increases greatly with maturity. Mineral and vitamin contents are low. We would have to say that sweet corn is eaten largely because we like it.

Most of the sweet corn sold fresh is boiled and eaten from the cob. Sometimes housewives cut the kernels from the cobs for soups, stews, fritters, and baked dishes. It is processed commercially in whole-ear pack, whole-kernel, and cream style. For the cream pack the rows are slit and the contents scraped and pressed out, most of the kernel wall remaining on the cob. It is frozen extensively in the same forms. Drying has been practiced for years, especially in southeastern Pennsylvania.

Botany

Sweet corn, *Zea mays,* a monocot, is a member of the grass[1] family, Gramineae, the greatest of all food-bearing families for man and animal It includes the cereal grains, wheat, rice, the grasses for forage and pasture, as well as bamboo. Sweet corn is a strict annual, growing from seed, developing stem and fruit, and dying after seed is mature.

The stem is characteristic of the grasses, with hardened outer wall and pithy center, through which the bundles are scattered. The tassel is the male inflorescence; the ear is the female. The husks are leaves, mostly sheath. Suckers are tillers or basal branches which may or may not develop tassels and ears. When water is scarce, leaves roll, as one surface dries out faster than the other; the rolling serves to curb the rate of evaporation.

Flower. Corn is monoecious (*monos,* one; *oikos,* household), having separate male and female flowers on one plant. The male flowers are of characteristic grass structure. Pollination is by gravity and wind, and pollen grains are produced in enormous numbers. In the ear, there is always an even number of rows because the spikelets are borne in pairs. A spikelet has two flowers, but in most varieties only one ovary develops. In some varieties, such as Country Gentleman and its hybrids, *both* flowers of a spikelet are fertile, and irregular arrangement of kernels results from the crowding. The silk is the elongated stigma and style.

The pollen grain alights on the silk, and the pollen tube must grow through its length to enter the embryo sac and accomplish fertilization. See Figs 7.1 and 7.4. Imperfect fertilization may result from the drying and killing of pollen grains or of silk in very hot dry weather and also from the failure of pollen to shed in cold wet weather.

Xenia. In most plants the characters arising from cross fertilization do not appear until the plant has developed from the seed, because the structures we see are parts of the mother plant. But if a row of white-kerneled corn is planted between rows of yellow corn, yellow kernels will appear in the ears of the white variety. This phenomenon is called xenia and is due to the fact that the pericarp or hull, which is mother tissue, is transparent, revealing the color of the aleurone layer which is part of the endosperm, arising from the secondary fertilization in the embryo sac. See page 98. Since yellow is dominant over white, the endosperm of every kernel that is fertilized by a yellow pollen grain shows that color. Those fertilized by pollen from the white plants remain white.

Breeding

On both theoretical and practical sides, the breeding of corn has received more attention than that of any other plant. Its variations, genetic factors, chromosome mapping, and behavior under selection and crossing have been the subjects of many investigations. See *USDA Yearbook*, 1937. Sweet-corn breeding has profited by these studies.

Hybrids from inbreds.[4] Probably the greatest advance in varietal improvement among the vegetables during the past two or three decades has been the improvement of sweet-corn varieties by the method of crossing inbred strains.

In 1908, G. H. Shull of Princeton showed that crossing of inbred lines of corn results in increased yield and improved uniformity. D. F. Jones of Connecticut in 1924 and Glenn Smith of Indiana in 1927 introduced varieties of sweet corn resulting from the application of this principle. Smith gave us Golden Cross, which is the most important of all sweet-corn varieties. Jones and Singleton bred Spancross, Marcross, and many others. As new hybrid varieties are developed, open-pollinated sorts are relegated to the past.

Inbreeding is accomplished by bagging both tassel and ear and then applying pollen to silk of the same plant. After six or eight generations this yields a stock that is very uniform in its characters, but it has lost vigor; the plant is small, with small, poorly filled ears and poor kernels. When pairs of inbreds are crossed, vigor is sometimes stepped up, often beyond

the level of either parent. This phenomenon is called ***heterosis*** or hybrid vigor.

With endless patience, breeders have developed many inbreds to be crossed in all sorts of combinations. A few of these combinations have been successful and have given us splendid varieties; hundreds have come to naught. Among the good ones are Seneca 60, North Star, Carmelcross, Golden Cross, Iochief, Aristogold and Seneca Chief.

D. F. Jones of Connecticut has led in developing male-sterile inbred lines to be used as female parents with good prospect that the laborious task of detasseling may be eliminated.

Seed production

Seed must be produced each year by crossing the inbred lines. Sowing of seed from crossed corn is not recommended, as the progeny in the F_2 generation shows the various combinations of characters that would be predicted under the law of Mendel, a mixed multitude.

Hybrid seed is produced by planting seed of the male parent in single rows between blocks of three or four rows of the female parent. The female plants are detasseled, and so pollination is necessarily from the single rows. Some producers of crossed corn seed maintain their own inbreds, and some develop new ones. Others buy inbred seed from breeders.

Top-crossed corn is produced by crossing an inbred male parent and an open-pollinated female parent. This method is practically obsolete for sweet corn.

Double-crossed corn results from crossing the progenies of each of two pairs of inbreds. This method results in a better yield of fuller and better-appearing seed, owing to hybrid vigor, and is much used for field corn. A *three-way cross* represents a hybrid between one inbred and the F_1 progeny of two other inbreds.

Curing seed. Sweet corn for seed is matured in about the same way as field corn, being allowed to ripen on the stalk. Moisture content must be brought down to about 15% before the seed can resist mold invasion and freezing injury. Erwin and Haber (*Iowa Sta. Bul.* 250) found that topping and shocking did not hasten curing, but opening the husks did. They discuss methods of kiln-drying which are desirable.

Importance

Only recently have figures been available on sweet corn for market, and data are still fragmentary as much of the crop is for local sale rather than for shipment.

The processing crop occupies over 450,000 acres, bringing farmers $20,000,000 to $35,000,000 annually. Leading states in acreage are: Wisconsin, Minnesota, Illinois, Indiana, Iowa, and Maryland. For full data see *Agricultural Statistics*.

Yields and returns

The average yield is about 6,000 ears per acre. Growers consider 10,000 to 12,000 ears a good crop. Processing yields for the United States average about 2½ to 3 tons per acre, in the husk. The processing price prior to 1942 averaged less than $10 per ton, though the farmer retains fodder and poor ears. In 1952 the average was about $24.

History

The American origin of maize is accepted, as there is no record of its culture before 1492. There are several theories about its origin, but no wild form that can be identified with cultivated corn is known. Mangelsdorf and Reeves,[12] in an ingenious weaving together of fragmentary evidence, of findings of archaeology, and of intelligent imagination, trace an interesting and plausible story of the probable cultural and genetic history of maize.

It has commonly been said that our first knowledge of sweet corn came when a Richard Bagnell, an officer in Sullivan's expedition which crushed the Iroquois Indians of Central New York, carried sweet corn seed to New England on his return from the campaign, but Erwin questions this conclusion. Who could say now that Captain Bagnell's corn possessed the characters that distinguish sweet corn as we know it? Erwin has found no sweet corn in archaeological museums. Lindstrom has found sweet corn as a mutation in dent corn. Erwin is of the view that sweet corn appeared in the early 1800's as a mutant in field corn, and perhaps more than once since.

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20

Root Crops

Beet	Turnip
Carrot	Rutabaga
Parsnip	Radish

Although the root crops belong to four different botanical families, they are similar in cultural requirements and in many other respects. They are commonly grown by market gardeners near most cities, but markets are readily oversupplied and prices drop quickly to levels that are unprofitable except under the most efficient production and handling. Large-scale production for long-distance shipment has increased markedly, especially with carrots. Home culture provides a large amount of good food from a limited area. A 20-foot row of carrots will provide six meals for six people even when the roots are still small and tender.

ADAPTATION

The root crops are grown rather intensively, with close rows, and many plants per acre. They formerly required more hand work than many crops, but high cost of labor has necessitated labor-saving methods, such as chemical weed control and precision planting.

Root crops need deep, friable soil that is well drained and well filled with organic matter. They should grow rapidly for heavy yield and high quality, and there must be an ample supply of moisture. If these requirements are not met, the roots are likely to be branched, misshapen, tough in texture, and unsightly. Thus, the root crops are usually found on sandy loam soils or on silty bottom lands and often on muck soils. It would seem that "pronginess" of carrots is determined when the tap root is making its way down into the soil during early growth. If it encounters some unfavorable condition such as a hard, dry, or

very wet layer of soil, a mass of fertilizer, a stone, or other obstruction, the root will branch, and then the mature carrots may be notable as grotesque specimens for the curio display at the county fair, but they will not be very suitable for selling. Other

FIG. 20.1. Carrot is a biennial, blossoming and seeding the second year.

factors are the presence of aster yellows and the use of fresh manure. Better shape in carrots usually results if soil is loose and bedded up.

The root crops vary in their soil-reaction relations. Beet and parsnip are acid-sensitive, the radish is tolerant, and the carrot and turnip are very tolerant.

The root crops are frost-hardy and thrive under cool weather conditions. In the south they grow well during the winter half of the year. Rutabagas thrive best where the summer is cool. A large share of our supply comes from Canada.

SOIL MANAGEMENT

Deep and thorough preparation of soil is required, first to insure good roots and second to insure an even come-up and stand. Plank drag, spike-tooth, and Meeker harrows are good to provide the requisite finished surface. Special implements are available for making up beds.

Market gardeners have long used manure freely on land to be planted to root crops, but supply is now restricted and green manure and commercial fertilizers are used. This makes choice of suitable land for these crops more important than when manure was abundant. Manure should be well rotted or applied long in advance of planting.

On heavier soils and with some manure a fertilizer of 1–2–1 or 1–4–1 ratio is likely to serve well. On light soils 1–1–1 or on muck 1–2–3 ratios may be suggested. As always, local advice is necessary.

Beets are sensitive to chlorosis due to manganese shortage. This element becomes unavailable when *p*H is too high, that is, when soil is on the alkaline side. Addition of manganese with the fertilizer or sprayed on the foliage is effective.

Boron deficiency has been shown [2] to cause an internal breakdown, canker, or dry rot of beets. This trouble is serious in dry seasons and on soils more alkaline than *p*H 7.0. Borax at the rate of about 50 pounds per acre afforded control in the central New York area where experiments were conducted. Such applications of borax may be harmful to soils more acid than *p*H 7.0 and to following crops, such as beans, that are sensitive to this element. It must always be remembered that *borax* is not *boron;* 100 pounds of the borax contains but 9 pounds of boron. Boron deficiency also occurs in rutabagas and turnips.

VARIETIES OF BEETS

Crosby Egyptian, Crosby, or **Early Wonder** is a slightly earlier variety of beet than Detroit and is flattened globe to oblate in form. A number of strains are available, varying in form, color, and character of top. There is as much variation among strains under the two names Crosby and Wonder as there is between them. **Detroit Dark Red** or **Detroit** is a trifle later than Crosby, round to flattened globe in form, and with a small

crown. Interior color is deep violet-red, appearing almost black, and shows very faint zoning. Color development varies with strains and also under varying conditions, high temperature being apparently unfavorable.

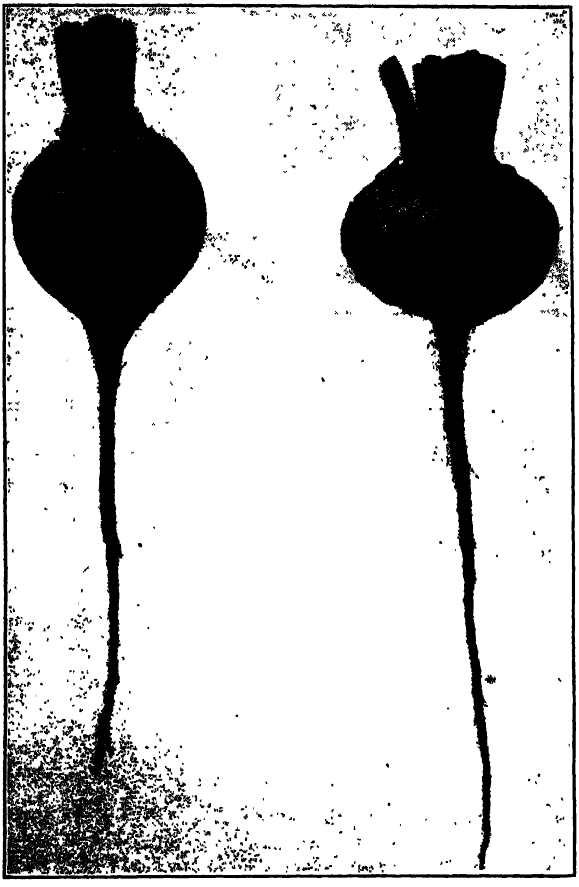


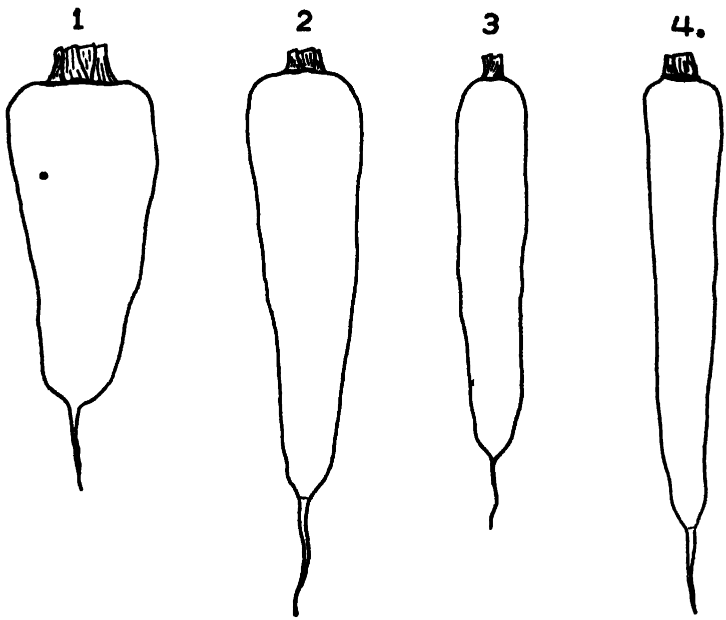
Fig. 20.2. Detroit and Crosby beets, the two leading varieties.

This is the leading canning variety and is widely planted for late market and in home gardens. Perfected Detroit shows slightly larger tops.

VARIETIES OF CARROTS

Carrots when pulled for home use or market are not usually sufficiently matured to show typical form, being more slender and more tapered at the base than fully grown specimens.

Chantenay and **Red-Core Chantenay** are short and somewhat blocky, about 5 by 2 inches when fully grown, stump rooted, somewhat square shouldered, smooth, and of good orange color in both core and cortex. Older strains showed lemon-yellow in core and orange-yellow in cortex, but "red-core" strains have been developed. It is largely grown for processing and for marketing with tops off.



After USDA Misc Publ. 361

FIG. 20.3. Carrot varieties. 1. Chantenay. 2. Danvers. 3. Nantes. 4. Imperator.

Nantes is of about the same length as Chantenay, narrower, cylindrical, round at top and base of root, with a small core, and of a deep orange color throughout. This variety is noted for high quality, but the tops are too small and weak for a good bunching variety.

The **Long Bunching** group includes **Imperator, Morse Bunching, Streamliner,** and others. These are long, rather slender, tapering from rounded shoulder to tip, and only slightly stump-rooted. Red-core character is general. These varieties are widely used for long-distance shipment and have increased in popularity for local selling.

VARIETIES OF PARSNIP

Hollow Crown or **Guernsey** is long and slender. **Model** is earlier, shorter, better filled at the sides, and less hollow at the crown. **Short Thick** is similar.

VARIETIES OF TURNIP

Purple Top Globe is the principal variety for home and market. The root is globular, white in skin and flesh, but with well-colored purple shoulder.

VARIETIES OF RUTABAGA

American Purple Top is a large, well-bred variety, round in form, smooth, heavily colored at the shoulder, with straw-colored flesh, and of high quality. **Laurentian** is superior in smoothness and uniformity.

Macomber is smaller and lower in yield than American Purple Top white in outside color and flesh, but of superior table quality.

VARIETIES OF RADISH

Early Scarlet Globe is a leading variety for home and market use. There are many strains, varying in shape and color of root, and size of

FIG. 20.4. Southern Market Globe radish.

top. It is globular to olive-shaped, about an inch in diameter at good edible stage, smooth, and of strong scarlet-red color. **Cavalier, Cherry Belle** and **Comet** are similar.

Sparkler shows a distinct white tip.

Icicle is pure white, long, slender, and of high quality.

PLANTING

Most root crops are spaced 14 to 18 inches between rows for wheel hoe, walking tractor, or riding tractor cultivation. Under irrigation, two rows about 12 inches apart are commonly grown on a raised bed between furrows, with 40-inch centers. Radishes are planted with rows 6 to 12 inches apart. Under tractor planting and cultivating, a wider wheel space may be left between gangs of planters or blades.

Seed is sowed with a small, single drill, pushed like a wheel hoe, or the drills may be mounted in gangs of three or four or more on tractors, with the operator either walking or riding. See Fig. 11.7.

Seeds of most root crops are small and delicate in germination, though radish germinates quickly and strongly. Care is needed to see that soil is well and smoothly prepared and that depth of covering and firming are uniform in order to insure even come-up and stand. Drills must be adjusted and watched closely so that the stand will be adequate and thinning will be rendered unnecessary or reduced to a minimum. Drills should be carefully tested on a floor or smooth road. It helps greatly to know the viability of the seed, as tested in similar soil. Seeds such as turnips, carrots, and parsnips differ not only in size but also in freeness of flowing through the drill.

The seed ball of beet is an inflorescence, hardened and dried, including pedicel, floral parts, and fruit, as well as seed. Hence there may be more than one plant per seedball and apparent germination of more than 100%.

Rates of seeding per acre vary widely. Carrot commonly requires 2 to 3 pounds per acre; beet, 5 to 6; radish, 10 to 12; turnip and rutabaga, about 2. See Table 11.3 for home garden rate.

A suitable stand in the row of most roots ranges from 6 to 8 plants per foot, somewhat closer for radishes, wider for rutabagas. Carrots stand some crowding fairly well. Beets are likely to be lopsided if crowded, and carrots and parsnips may be marred by twisting about each other.

In the home garden, thinning of root crops is fairly common. Thinnings of beets make good greens to cook. In large-scale plantings for processing or shipment, the practice has been largely abandoned, growers figuring that a slight deficiency of stand is overbalanced by the saving of labor.

Carrot and parsnip seeds should seldom be covered over ½ inch deep, as they germinate slowly and rather weakly. If crust forms on some soils before germination, a light raking, rolling with a light wooden roller set with nails, or some similar practice, judiciously applied, may be useful. Irrigation will also solve the problem.

In dry weather, rows for planting may be made somewhat deeper than usual, but the covering should be only ½ inch or so and the soil should be firmly pressed over the seed.

Morse Bunching

Packed Normal Ridged

Fig. 20.5. Effect of soil packing (*left*) versus loose soil (*right*) on shape of carrot roots.

WEED CONTROL

Root crops should not be planted in soils badly infested with weeds. Effective year-to-year control of weeds is a great asset. Most root crops have rather restricted root systems, and deep cultivation does serious damage.

Some growers apply a manure mulch over radishes just after planting to conserve moisture, to insure even come-up, to smother weeds, and perhaps to keep the soil somewhat cooler than otherwise.

The light hydrocarbon oil Stoddard solvent is widely and successfully used for weed control in carrots, 40 to 80 gallons per acre according to size of plants. If used within a month of pulling, however, carrots are likely to develop off-flavor.

A solution of common salt, NaCl, 2 pounds per gallon, 150 to 200 gallons per acre, is effective to control some weeds in beets.

IRRIGATION

Irrigation is of great value for root crops and is widely used in all regions. A steady and adequate water supply makes for rapid growth, heavy yield, and high quality. Overwatering may result in tops that are too large and succulent. Dryness of soil, followed by rain or irrigation, is likely to cause growth cracks, especially with carrots.

INSECTS AND DISEASES

Maggots of various sorts are probably the worst insect enemies of root crops.

Carrot rust fly, *Psila rosae,* in the larval (maggot) stage burrows in roots, causing rusty discoloration in addition to direct damage. Adjusting the time of seeding in relation to the broods is of service in control.

Cabbage maggot, *Hylemyia brassicae,* infests radish and turnip. On a small scale, calomel is useful, 1 ounce to 10 gallons of water, applied two or three times at weekly intervals along the rows so that the suspension will moisten the soil about the roots. Chlordane is also effective.

Carrot yellows is a virus disease transmitted by the six-spotted leaf hopper. DDT is effective.

MARKETING

The preparation of carrots for market illustrates the methods followed with all the root crops, the most important of which are carrots, beets, radishes, turnips, rutabagas, and parsnips. In general, carrots and other roots are marketed tied in bunches with tops on, or in baskets, bags, or in bulk with tops off.

Maturity is largely a matter of size. Early in the season carrots of ¾-inch diameter are salable. Later full-grown roots are available. Oversize roots are not desirable as they are less attractive than smaller ones. Experiments [4b] have shown that large carrots have as much sugar as small ones, and the fiber content is no higher, but there seem to be other differences in texture that render them less desirable. It is better to have successive plantings and to pull as soon as roots have reached

appropriate size. The housewife wants them young and of small to medium size.

Tops on or off. The early market garden crop is almost always sold in bunches, but later, tops are removed before selling Some

Union Pacific Railroad

FIG. 206 Carrots are usually tied in the field with grasslike raffia or twine and more recently, as here, with "Twistems," a combination of paper and wire, carrying a label Note the long, slender roots, pulled before fully mature.

of the carrots shipped from Texas and California are handled with tops on, in spite of the fact that freight, packaging, and handling are paid on the tops that will be twisted off by the grocer and thrown under the counter to be disposed of later.

Tops rob roots of water, causing shriveling, and perhaps also deplete them of materials of food value. This waste is probably tolerated because the housewife regards the tops as evidence that the carrots are young and tender. Tops also have cushioning value in the package and the freight cost factor may be overrated by some. There is now considerable interest in shipping topped carrots in bags of transparent film.

Bunched carrots. Marketing of root crops with tops on is usually handled rather informally, especially by market gardeners. Large growers and shippers have more elaborate equipment and methods for the purpose.

Tying. A widely used tie, called "Twistems," is made of wire laminated between two narrow strips of tough paper, which is

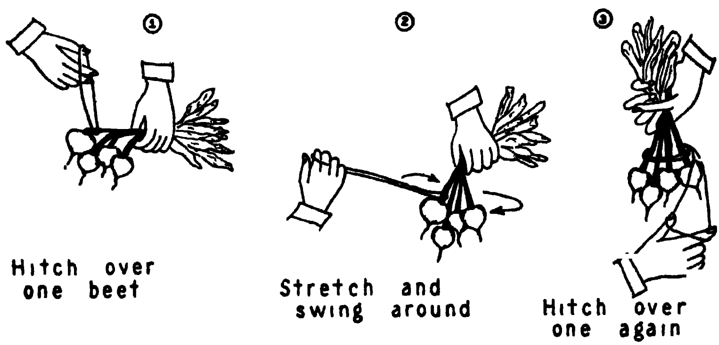


FIG. 207 Rubber bands are widely used for bunching This shows how to solve the awkward problem of holding the bunch and getting the band on with only two hands.

often printed; it is fastened by simple twisting. Other materials available for tying are white cotton twine, jute twine, raffia, and rubber bands. String is cut to the proper length, and the worker takes a bunch of it under his belt. Kneeling, he pulls the carrots and ties them just above the roots, picking off yellow or dead leaves. Carrots are sometimes tied by machines designed for the purpose. The number in a bunch varies widely. Often, as the price falls, growers vie with one another to see how many they can give in a bunch. For shipment, size of bunch is gauged so that 60 bunches, each about a pound of root, fill a Western lettuce crate.

Washing. As dirt washes off more easily if it has not dried on, carrots should never be allowed to remain long on the ground, and bunches should be laid down so that the tops cover the roots. Some growers prefer to have carrots pulled, laid straight on a sled or in crates, and taken to the packing shed for bunching and washing.

For methods of washing see Chapter 4.

Packages. Among the common packages for carrots with tops on are the Los Angeles lettuce crate and the half crate of the same length. On local markets, second-hand packages of various sorts are used.

Topped carrots. When carrots are to be sold with tops off, they are pulled and topped in the field and put in crates. Few are sold without washing, although it is said that they store better if unwashed. Many washers, homemade and manufactured, are in use. Most of them are rotating cylinders with a perforated spray pipe as an axle. One type is loaded, turned a while, and discharged. On a larger scale, there are cylinder washers with feed hopper at one end and discharge at the other.

Both types usually discharge either onto a sorting table or a sorting belt. Here culls are discarded and No. 1 and No. 2 carrots are separated if two grades are made. Bags of paper mesh or burlap carrying 50 pounds are commonly used. The use of polyethylene bags containing 1 pound of carrots is increasing.

The U. S. Department of Agriculture has issued standards for grades of carrots and of other root crops which are applied under the same principles as those for tomatoes and potatoes.

MARKETING OTHER ROOTS

Early beets are harvested when they reach a size of 1¼ to 1½ inches. It is well to move them out before they become too large. Prices usually drop quickly on local markets. It is better to sell bunches of 4 little beets at $1.00 a dozen bunches than to sell 6 big ones at 40 or even 25 cents a dozen bunches.

Beets, both top and root, wilt more quickly than most root crops. Careful packaging and protection and use of spray heads on retail stands are helpful in this connection. Retailers

should not buy far ahead, and they should keep part of the supply in a cold room of high humidity.

Beets for cannery are pulled, topped, sometimes by machinery, and sorted at the factory for size. A sample price scale is: up to 1¾ inches, $30 per ton; to 2½ inches, $14; to 3 inches, $7; over 3 inches, acceptance optional.

Parsnips are sometimes left in the ground over winter, and people say that they are sweeter in the spring. This is supported by experiments by Boswell,[8] who found that sugar content increased under indoor storage at 32° to 34° F. as much as in those left in the field for two months. Sugar content on the dry-weight basis more than doubled in 19 days at 34° F. Parsnips will withstand freezing, but this is not necessary for increase in sugar content.

Rutabagas are commonly waxed, before shipment, by dipping in heated paraffin. Details have been worked out experimentally by Canadian experiment stations, particularly the Ontario Agricultural College at Guelph.

Radishes are pulled, bunched, and fastened, often with rubber bands. The count per bunch varies widely from 8 to 30 or more. After washing, they are packed in bushel baskets or in the small lettuce crate. Because tops turn yellow readily, package icing is good practice. Radishes should be harvested before they become pithy.

CONCERNING BEETS

Beets possess no outstanding nutritive value over other vegetables, but they are recognized as a good and useful food. They are commonly boiled and served with butter or a sauce and are often pickled at home.

Beet, *Beta vulgaris,* belongs to the family Chenopodiaceae * along with spinach and Swiss chard. It is a herbaceous biennial forming a root and leafy top the first year. The second year, the disclike stem elongates, and flowers and seeds are produced. The calyx lobes of the flower become thick and hard, clasping and enclosing the fruit. One or several of these flowers makes up a cluster or seedball, ordinarily called a seed, which dries and

* Greek, *chenos,* goose; *pous, podos,* foot; goosefoot family. Some wild forms have leaves shaped like the footprint of a goose.

is harvested. The seed itself is about ⅛ inch long, a rich glossy brown, and shaped somewhat like a comma with a large body and small point.

Chroboczek[8] found that growth at a temperature of 50° to 60° F. resulted in first year seeding of beets. Long light-period hastened the seeding process. Plants exposed for 30 days to a temperature of 40° to 50° F. and then grown at 60° to 70° F. also seeded. Higher temperature tended to nullify the effect of low temperature. A long day favored seeding of plants grown at high temperature. Evidence appears that the effect of light is localized in the region of the growing point, as was found by Knott with spinach. Compare the seeding behavior of beet with that of celery, Chapter 7

The substance responsible for the color of beets has been isolated and identified as betaine. Thus, a quantitative measure of color has been developed, and it is being used to determine the effects of heredity and environment on color. It is known that a well-bred strain of beet may color poorly under certain conditions, temperature probably being important.

Pollination is by wind, and many strains are self-incompatible.

Beets are widely grown for the local market. Texas is the principal shipping state, with over half of the nation's reported acreage. Cannery acreage is mostly in northern states and is about twice the market acreage; the two together amount to about a third the carrot area. The widely scattered production of crops for local market is not adequately reported in crop estimates.

Nation-wide average yield of beets for market is 200 bushels (52 pounds) per acre and 8.75 tons per acre for processing. Yields of 300 to 500 bushels per acre are not uncommon. A Los Angeles crate of bunched beets or carrots makes about a bushel with tops off.

CONCERNING CARROTS

The carrot has greatly increased in nation-wide popularity in the past fifty years. Its high content of carotene, the precursor of vitamin A, gives the carrot outstanding nutritive value. Carotene is the yellow pigment of carrots and is also abundant in leafy vegetables, being associated with chlorophyll.

Carrot acreage has risen rapidly from 8,000 acres in 1923 to about 80,000 acres in 1952. It is now approximately a $50,000,000 crop.

California plants more than a third of the fresh market acreage of carrots, and Texas about a fifth, with Arizona and New York following.

Carrots for processing are becoming important, but separate statistics are lacking.

The average yield per acre is about 375 bushels of 50 pounds each, but 700 bushels have been harvested from an acre.

Carrot, *Daucus carota,* belongs to the family Umbelliferae * along with celery, parsnip, parsley, and many wild plants such as wild carrot, wild parsnip, and poison hemlock. Wild carrot is of the same species as the cultivated and is distinguished by one purple floret in the center of the inflorescence. As a flower, it is called Queen Anne's Lace. The plant is biennial, its life history similar to that of the beet. Each flower develops a double fruit, each half carrying a single seed. We plant the fruit, which is ribbed, and which, before milling, is spiny. It contains tubes of oil of an aromatic odor characteristic of most Umbelliferae.

Pollination is by wind and insects. Some pure-line breeding work has been done, but most of the improvement has been by mass selection.

Barnes [4] found that carrots grew better and showed better color at 60° to 70° F. than at temperatures either higher or lower. Carrots grown at lower temperatures than this were slender and poorly colored—a difficulty that has caused some concern in the south. Higher temperatures were also found unfavorable for good color. Barnes found little difference in color traceable to soil moisture, though workers in Louisiana have offered evidence to this effect. Neither length of day nor nutrients within ordinary limits had any great influence on color. Older carrots show more carotene than younger ones.

CONCERNING RADISHES

The radish is distinctly a minor vegetable of no specially marked nutritive value but prized as a relish or appetizer and

* *Umbra,* shade, referring to the umbrella-like inflorescence; *fer,* carry or bear.

for its color. It possesses the pungency characteristic of the crucifers, a property which is unpleasantly exaggerated when the crop grows under adverse conditions.

The radish is widely grown in market gardens, and large areas are planted for shipment in South Carolina, Louisiana, Arkansas, and Texas.

Radish, *Raphanus sativus,* is of the family Cruciferae. Its life cycle is similar to that of other roots, but it is an annual rather than a biennial.

Breeding has been largely by mass selection. Self-incompatability occurs, but some strains are self-fertile.

Mahrouki (unpublished thesis, Cornell) has compared the performance of radishes in a greenhouse under various conditions of temperature, moisture, and light. He finds 50° to 60° F. preferable, considering time required to mature as well as size and quality of roots. Increased day length, 15 hours in winter, resulted in overgrown foliage. Liberal moisture supply favors rapidity of growth, yield, and quality. Premature seeding is favored by both long photoperiod and high temperature.

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21

Peas and Beans

There are many forms of peas and beans, and some confusion exists, even in the use of these simple terms.

Both peas and beans belong to the legume family, Leguminosae, with characteristic butterfly-like (papilionaceous) blossoms.

Many varieties of cow peas, *Vigna sinensis*, are valued as human food, and these are coming to be known as "southern peas."

To distinguish them from field and dried or split peas, garden peas are often called green peas or, in the south, English peas. Beans are used as immature pods, snap beans; as immature seeds, green shell beans; or as mature dry beans. Snap beans should never be called "string beans"; the use of stringy varieties is quite unnecessary, since excellent stringless varieties have been bred. The term "butter beans" is variously applied to wax podded snap beans and to Lima beans, especially the small or Sieva group.

Legumes are nitrogen gatherers. On the roots of legumes live bacteria, *Rhizobium* spp. and *Pseudomonas radicicola* (*radicicola*, root-inhabiting), which have the capacity to take some of the enormously abundant free nitrogen of the atmosphere and transform it into chemically combined nitrogen which can be used by the plant and so made available to animals and man. The plant furnishes carbohydrate for the bacteria. This relation between the plant and bacteria is called *symbiosis*, living together. On the roots are found little knobs or nodules, resulting from abnormal gall-like growth of plant tissue, due to the presence of the bacteria. Legumes, fully grown and plowed into the soil, may add from 100 to 200 pounds per acre of nitrogen, the equivalent of 300 to 600 pounds of ammonium nitrate which costs commonly around $80 a ton.

Adaptation. Both peas and beans leave a considerable weight of organic matter for the soil which is especially valuable on account of the content of nitrogen gathered from the air. Peas and most beans mature in a short time from seed—in 6 to 10 or 12 weeks, according to variety, climate, and weather. Thus the land may be planted afterward to another market crop or

Wash Expt Sta

FIG. 211 In Washington state peas are supported with posts and wire This is a variety trial, but the practice is followed for commercial plantings Washington peas often command twice the price of eastern peas on New York market.

to a soil-improving crop such as rye or soybeans. The vines of processing peas often go into a silo or stack to be used as cattle feed, but, even so, most of both nitrogen and organic matter can return to the land if operations are well managed. Fermentation in the silo pretty thoroughly destroys weed seeds. After peas or beans have been picked for market, plants should be plowed under promptly to avoid waste of the organic matter.

PEAS

CLIMATE

Peas and beans differ markedly in temperature relations. Peas are very hardy to frost but not to heat. Hence, even in the

north, early planting is necessary to insure maturity before hot weather. Boswell[3] has showed that yield per plant from late plantings may be only half as great as yields from plantings made six weeks earlier. Summer peas are successful only in areas of high elevation and cool weather, as in some parts of New England and New York. Mildew is especially troublesome late in the season.

Walker (*N. Y., Cornell, Sta. Bul.* 475) using data from a single western New York farm over a period of twelve years, found a very close correlation between June rainfall and yield.

Soil Management

Soils. Uniformity of maturity is of major importance for peas for processing. Hence it is well to select fields that are uniform, level, and well-drained. Peas as well as beans are grown on a wide variety of soils from sandy to fairly heavy. The *p*H range is approximately 5.5–6.7.

Fertility. When fertility has been well maintained, peas do not require very heavy fertilizer applications. They may be regarded as making economical use of nutrient reserves remaining after other crops. These reserves, however, will not meet their needs if soil is poor or if the previous crop has not been at least reasonably well fed. As a rough guide one may consider, for light soils, 40 to 50 pounds per acre of nitrogen and 50 to 80 pounds each of phosphoric acid and potash, and, for heavier soils, 30 to 40 pounds each of nitrogen and potash with 50 to 80 pounds of phosphoric acid. Examples would be a 1–2–2 ratio, say 450–600 pounds per acre of an 8–16–16; and a 1–2–1 ratio for heavier soils, say 600–800 pounds per acre of 5–10–10.

Band placement of fertilizer has given excellent results with peas, but great care must be exercised not to bring the material into contact with seeds, as they are highly sensitive to fertilizer injury. Planting machines with placement equipment are available.

Preparation. Since seeds of peas are large and germinate with vigor, good ordinary general farm preparation of soil is adequate. At the same time, failure to reduce clods and to fit the land well often results in poor stands and reduced yield.[4]

Varieties

A good variety of peas should be productive, mature uniformly, have large well-filled pods, be of dark green color, and retain color well. High table quality involves sweetness, flavor, and tenderness of seed coat. Resistance to fusarium is important in many areas. See refs. 12 and 13, Chapter 8. Where fusarium wilt is prevalent, it is necessary to procure seed of wilt-resistant strains, which is generally available.

For home and market

Laxton Progress is early, with dwarf vine, yielding large, well-filled pods of high quality.

Little Marvel is a trifle later than Progress, has smaller vines, and is very prolific. Pods are small but well filled and of high quality so that it is an excellent home variety but not acceptable on most markets.

Thomas Laxton is second early, is of medium height, and has dark foliage. It is an excellent yielder of good-sized, dark-colored, well-filled, square-ended pods. It is popular for freezing along with **Freezonian** and **Oneida.**

Wando is a medium-early variety that does better than most under warm weather conditions. It is useful in the south and in northern midsummer, though quality does not rank with the best.

The Stride group includes several names: **Giant Stride, Asgrow 40, Morse Market,** and others. These are later than Thomas Laxton, of medium height, vigorous in vine and foliage, large podded, and well filled.

Alderman is late, 4 or 5 feet tall, vigorous, and the heaviest producer of all home and market varieties, yielding handsome, large, well-filled, pointed pods.

Stratagem is a good late variety of medium height, similar to the Stride group.

For processing

Seedsmen offer many varieties and strains for processing, different ones being adapted for different areas. The following may be used as a basis of comparison for the others.

Alaska, in spite of inferior table quality, is still important. The vine, which is slender, light green, and of medium height, is highly productive of small, square-ended, well-filled pods. Seed is smooth. Most other varieties now planted have wrinkled seeds.

Surprise is early, prolific, and medium in vigor, height, and color of vine. Pods are small and well filled. Quality is much better than Alaska. **Wisconsin Early Sweet** is a fusarium-resistant strain.

Perfection is the leading midseason or late processing variety, of excellent vine and very prolific, yielding peas of high quality.

Favorite varieties for freezing are Thomas Laxton, the Strides, and Alderman.

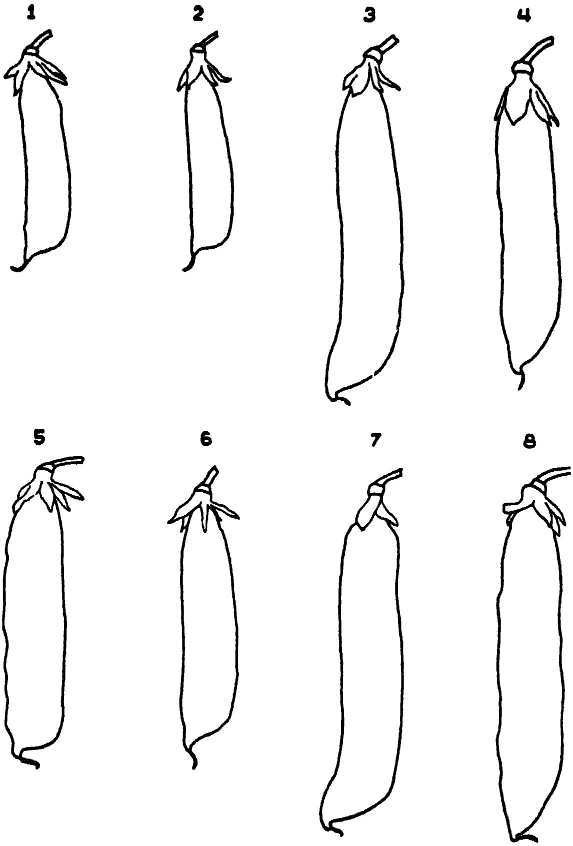


Fig. 21.2. Varieties of green peas. 1. Alaska. 2. Surprise. 3. Progress. 4. World Record. 5. Thomas Laxton. 6. Perfection. 7. Giant Stride. 8. Alderman.

Planting

Since peas will not thrive under hot, dry weather conditions, early planting is important in most places. In the deep south, local guidance will have to be followed. From there northward, plantings should be made about as soon as the ground can be prepared. Even severe frosts do little harm. Varieties differ slightly in this respect, but one of the best ways to achieve a succession is to plant early, midseason, and late varieties at the same time, for example Laxton Progress, Morse Market, and

Stratagem. Later plantings are feasible only where midsummer weather is cool.

The degree-day or heat-unit system (see page 203) has been widely used for peas. Main-crop varieties require about 2,000 degree-days or heat units to mature, assuming 40° F. as a base. A delay in maturity of one day represents about 35 heat units, if the temperature at planting time averages 50° and at harvest time 75° F. Thus to account for one day's difference in maturity would require 3½ days' difference at planting time ($75 - 40 = 35$; $50 - 40 = 10$; $35 \div 10 = 3\frac{1}{2}$). But remember, other factors enter.

Rate of planting. As seed is usually the most costly item in growing peas and beans, the rate of planting should be studied carefully. For home and market, peas are planted in rows 2 to 3 feet apart for horse or tractor cultivation, seed being sowed at the rate of 1½ to 2½ bushels per acre. In the home garden a pound is considered enough for a row of 100 feet. Planting rate may range from 6 to 12 seeds per foot.

For production for processing, seed is planted with a grain drill in rows 7 inches apart. Sowings of 4 to 5 bushels per acre are recommended, both yield and cost of seed being taken into consideration.

Variations in the size of seed affect the rate of planting more than is commonly realized. Seed should be tested for viability as a guide in setting the planting rate.

Seed is sowed from 1 to 3 inches deep, at the greater depth in drier and sandier soils and for later plantings.

Seed treatment is necessary in most places to forestall disease damage to seedlings. Spergon and arasan are used.

Inoculation with the proper legume bacteria may be required when peas have not been grown previously. The material may be procured from commercial sources or, in some states, from the state agricultural college. Inoculation and seed treatment for disease control may be incompatible.

Later Care

Weed control. If peas are planted with the grain drill, cultivation or weeding may be omitted or the ground may be worked with a spring-tooth weeder or rotary hoe.

Chemical weed control, chiefly against mustard, is largely by use of dinitro spray, or cyanamid dust or granules which carry nitrogen in addition to weed control value. Common salt is sometimes used. With all these, directions must be followed carefully, including attention to size of plants and weather conditions to avoid injury.

Training. Tall varieties of peas are often trained in home gardens, though many prefer to use dwarf or medium-height varieties. Brush and poultry wire are suitable. In some western shipping sections pea vines are trained to poles, twine, or mesh, and excellent pods are harvested.

Irrigation is less commonly practiced with peas than with vegetables requiring a longer growing season. Peas are usually grown at seasons of good moisture supply. New Jersey growers have found, however, that irrigation has practically doubled yields in some years.

Diseases and Insects

Failure to come up and make a good stand is common in peas because of damage caused by various fungi. Spergon or arasan seed treatment is effective.

Root rots, traceable to various fungi, frequently reduce the yield of peas. Definite measures for control are not available. Good drainage, rotation of crops, ample fertility, and other conditions favorable for a quick start and rapid growth are of some service. Use arasan or spergon as above.

Fusarium wilt is caused by *Fusarium* spp., which, like other fungi of this genus, lurks in the soil, enters by the roots, and interferes with water passage in the plant. The only control is choice of resistant strains, which are now available in most of the important varieties.

Powdery mildew, caused by *Erysiphe polygoni*, appears as a dusty white coating on the under sides of leaves. It is more troublesome in summer and fall than in the spring. Dusting with sulfur is of service but is scarcely practical on a large scale.

Leaf blight, caused by *Ascochyta* spp. and *Mycosphaerella* spp., appears as dark streaks on the stem and spreads to the leaves and pods. Use of clean seed from western irrigated areas or dry-land areas affords the only satisfactory control.

Aphids, *Macrosiphium pisi*, infest peas throughout the nation. The aphid or plant louse winters on legumes, including clovers, spreads to peas, and multiplies prodigiously, especially in warm, dry weather. Shoots and leaves are curled, blossoms are blasted, and pods are deformed by aphid activity. Dusting with parathion is recommended. Vaporized nicotine and rotenone spray are also used.

Pea weevil, *Bruchus pisorum*, and bean weevil, *Bruchus obtectus*, harbor over winter in the seed. The bean weevil multiplies in storage; the pea weevil does not. The pea weevil causes field damage; it is controlled with parathion or rotenone dust. Fumigation of seed after harvest with carbon bisulfide is effective.

Harvesting and Marketing

It is important that peas be harvested at the proper stage of maturity, when seeds have attained practically full size but have barely begun to harden.

Peas from the home garden should be on the table 30 minutes after they are picked, for they decline rapidly in quality after harvest, losing sugar and flavor, increasing in starch, and becoming hard. Sayre and associates [5b] have offered evidence indicating that thickness and toughness in seed coats are due to high calcium content.

Peas for market are picked by hand, usually by piece work, at, say, $1.00 a bushel. Previous to 1940, 35 cents a bushel was a common figure in New York. Only very high prices justify the cost of picking when the harvest is sparse. Selling peas in the pod is a declining business since freezing avoids shipping useless pods and preserves quality more easily and effectively.

Peas for canning and freezing are cut with a mower, windrowed, and loaded by hand or with a hay loader. Special harvesters are coming into use. See Fig. 21.3. At the factory or viner station, vines and all are fed into large machines which shell out the peas. A combined harvester and viner is under development, to deliver shelled peas and leave the vines in the field.

Time of harvest must be judged with great care: too soon, low yields; too late, poor quality. Quick processing is required, as the peas are slightly bruised and deterioration is henceforth rapid.

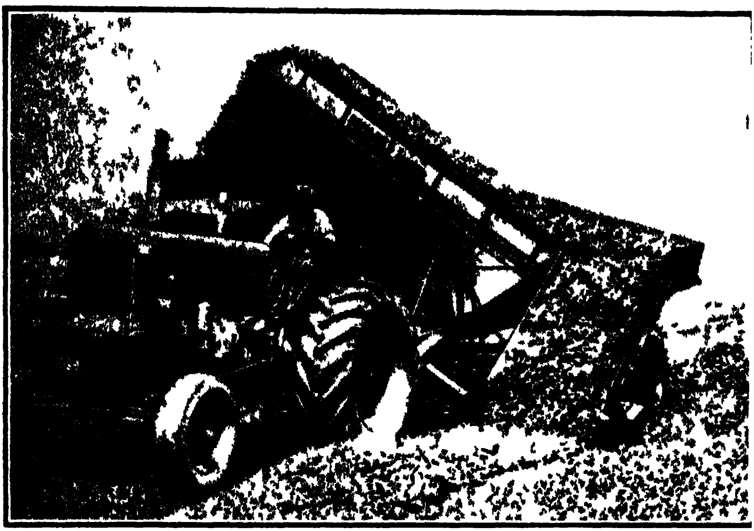


Fig 21 3 Cutter and loader for peas for processing

Sorting and cooling. Both peas and beans for fresh market are often run over sorting belts for removal of off-grade pods Precooling and keeping cool are important for peas Beans deteriorate less rapidly than peas Platenius (see ref 5 in Chapter 4) found that, in peas, sugar depletion was 2 6 times as fast at 68° F. as at 50° F and 1 5 times as fast at 86° F as at

68° F. This represents a rough expression of the law of van't Hoff, though many factors other than temperature are involved.

Precooling is best accomplished by immersing the pods in very cold water. The pods are freshened by imbibition; the danger of disease through wetting is negligible if the temperature is kept low. Ice is often put in containers of peas coming from the west.

Packages common for shipping are bushel baskets and bushel hampers. Bags, lug boxes, and square braid baskets are used locally. Wire-bound crates are common in the west. A bushel is usually considered to be 30 pounds in weight.

Concerning Peas

Food use

Green peas, freshly shelled, rank highest in protein among the fresh vegetables, Lima beans excepted. They rank high in calories and in ascorbic acid (vitamin C), low to medium in the other vitamins. Most of the peas are used shelled, either fresh or canned or frozen. They are usually cooked with a little water and served. Occasionally they are creamed or put in soups. Pea soup, however, is usually made with dried split peas, which are not considered here.

Botany

The pea, *Pisum sativum,* belongs to the Leguminosae, a large family ranging from quick-growing herbs to such trees as the locust and acacia. Related plants include, besides beans, the clovers, lentils, vetches, peanuts, cowpeas, the lupines, sesbania, lespedeza, sweet peas, and wisteria. They are scattered world wide and grow in almost all climates.

Flowers, white or purple, occur at leaf axils, usually in pairs, but in most garden varieties only one develops. Many processing varieties bear pods in pairs. The ovary is a true pod or legume, illustrating well the principle that floral parts are modified leaves. The seed structure represents buds forming on the margin of an infolded leaf. Pollination is almost wholly by selfing.

Breeding and seed

Peas have received the attention of breeders for many years, Thomas A. Knight having begun work in England in 1787. See

ref. 13 in Chapter 8. Wrinkled peas seem to date from his time. A Dr. McLean, also in England, developed important varieties, including Advancer, the predecessor of Perfection. Another Englishman, Thomas Laxton, has contributed Thomas Laxton, Laxtonian, and Laxton Progress. More recent work has centered on improved type, disease resistance, and uniform maturity for canning and freezing A number of seed houses employ well-trained breeders who are working constantly and are achieving improved strains both as to type and disease resistance.

Seed is produced largely in Idaho, Montana, and California.

Importance

Production of peas for fresh market has declined steadily since 1936 while processing has climbed. In 1952, 426,000 tons of shelled peas were grown for processing, while only 10,000 tons, shelled basis, were grown for fresh market. The canned pack was still 2½ times the frozen pack in 1951, though freezing has gained rapidly. Wisconsin in 1952 produced over 125,000 tons of shelled peas for processing, mostly for canning. Washington and Oregon grew another 125,000 tons, mostly for freezing.

Yields, costs, and returns

The average yield of market peas is only about 100 bushels of pods per acre, but Washington records an average well over 200 bushels. With favorable conditions good growers harvest 250 to 350 bushels per acre. For processing, the average for 1941–1950 was 2,280 pounds of shelled peas per acre. Yields of 4,000 and even 5,000 pounds are occasionally achieved. Pods shell out one-third to two-fifths their weight in peas.

Seed is the largest cost item in producing peas, other costs being relatively low.

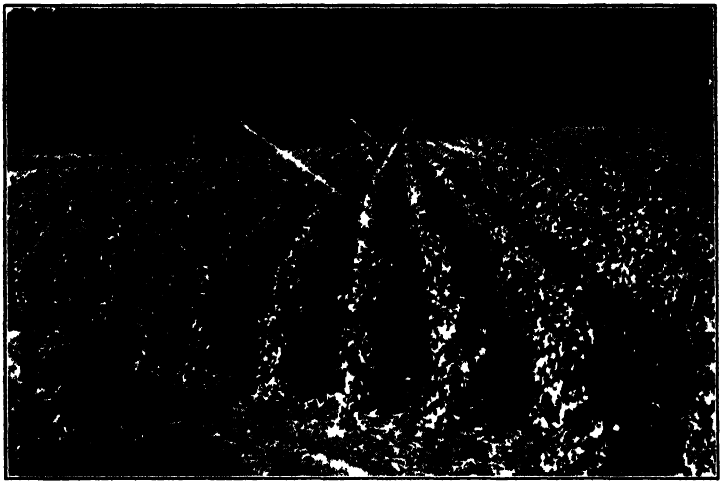
History

Leguminous seeds were undoubtedly used by man from very primitive times, but there is almost no way to be sure just what species were meant by ancient words in various languages. It is hard to differentiate among peas, pulse, lentils, and the like, especially when these words may have had meanings in early

English different from those of today. One writer reports that explorers have found peas among relics of the Stone Age and the Bronze Age.

GARDEN BEANS

Beans, differing from peas, are sensitive to frost and grow well under moderate summer temperatures. Limas and some of the



Ore. Expt. Sta.

FIG. 214. Beans for cannery of the high-quality Blue Lake variety are grown on posts and wire and twine in Oregon. Cost per acre is high, but cost per ton is low, and western canners compete strongly on eastern markets in spite of transportation charges. Rotary sprinkler irrigation.

southwestern varieties, grown for dry beans, withstand heat and drouth better than garden beans. Limas also require a longer growing period.

Aside from frost danger, beans do not thrive unless the soil and weather have become moderately warm, being comparable to corn in this respect.

SOILS

Beans grow well on a wide variety of soils; the pH range 5.5–6.7 is satisfactory. Fertility is maintained and soil is prepared much as for peas.

Varieties

Bush snap beans differ little in earliness, except that the Refugee group is late. Most bean varieties are readily separated by form and color of seed. Seed samples furnish good laboratory material for identification at any season. Such an exercise, to be most useful, should associate seed characters with other characters and with the merits and demerits of varieties. See refs. 12 and 13 in Chapter 8.

A good variety of bush bean is vigorous and upright in growth, holding pods well off the ground, prolific, uniform in maturity, producing pods that are well colored, straight, fleshy, stringless, with little fiber, and, preferably, round podded.

Bush, green podded

Tendergreen is a round-podded green snap bean of fine appearance and quality. It does not yield quite as well as **Black Valentine**, nor does it stand shipping so well.

Fig. 21.5. Asgrow Black Valentine.

Bountiful is a widely planted variety for fresh market, flat-podded, rather thin walled, and of poorer quality than the round-podded group. **Plentiful** is similar.

Among new green-podded bush varieties, **Topcrop** is highly productive, resistant to common bean mosaic and the "greasy pod" virus, round-podded, of high quality, but less attractive in appearance than some.

Wade is later than Tendergreen, resistant to common bean mosaic and to powdery mildew. Pods resemble those of Tendergreen, but are darker green.

Contender is resistant to common bean mosaic, to "greasy pod," and partially to powdery mildew, and yields well. Pods are longer and rounder, but more curved than Valentine.

Refugee, of which there are now many strains, is late, marked by a large, very prolific, much-branching plant, with small leaflets. Pods are short, round, and pale green in color. It is the leading canning variety. **U. S. 5** and **Idaho Refugee** are resistant to mosaic.

Bush, wax-podded

Pencilpod is a round-podded wax bean of high quality. **Prolific Wax** and **Brittle Wax,** or **Round-pod Kidney Wax,** are also round-podded varieties, popular for canning as well as for home use. **Kinghorn** is a white-seeded version of Round-podded Kidney Wax.

Surecrop is a flat-podded wax bean. **Cherokee** is a wax bean resembling Black Valentine.

Pole beans yield over a longer period of time than bush beans and have long, twining vines that require support.

Pole, green-podded

Scotia or **Striped Creaseback** is one of the best of the pole beans for quality. Pods are round, fleshy, stringless, and meaty. **Blue Lake** or **White Creaseback** is similar and widely grown in the Pacific states for home market and processing. It has not proved suitable for processing production in the northeast. The several strains vary in growth, yield, and earliness.

Kentucky Wonder is the most popular pole bean. Pods are oval in cross section, long, curved, occasionally somewhat gnarled, fleshy, and stringy, but of good quality when taken young. White-seeded strains are available.

Pole, wax

Kentucky Wonder Wax and **Golden Cluster** are pole wax beans with flat pods.

Bush, Lima

Henderson is an early, small-podded, small-seeded variety, very prolific and excellent for canning and freezing. It is a small Lima or Sieva bean, not a large Lima bean. **Triumph** is thicker seeded and heavier in yield.

Fordhook 242 is a large Lima with pods of medium length, usually with 3 or 4 medium-size seeds which are very thick and plump; it is often described as a potato Lima and is widely grown for home and market. Some still prefer Fordhook.

Burpee Bush has large pods and big flat seeds.

Baby Fordhook and **Baby Potato** represent selections from crosses designed to combine the hardiness and prolificacy of Fordhook with the quality of the small bean. Green seed character is desired by canners.

Pole, Lima

Carolina or **Sieva** is the pole version of Henderson. **Challenger** corresponds to Fordhook and **King of the Garden** to Burpee Bush.

Green shell

Beans harvested and shelled out after the seeds are nearly or fully grown, but before they have hardened and dried, are called *green shell beans.* The **Horticultural,** pole and dwarf, are leading varieties for the purpose. **Scarlet Runner** and **White Dutch Runner** are green shell beans producing showy red and white flowers, valuable for ornamental as well as culinary use. Ordinary varieties may be used as green shell beans if taken at the proper stage.

Planting

Bush beans are planted in rows for cultivation, 2 to 3 feet apart, a little more thinly than peas; ordinarily 1 to 1½ bushels of seed is required per acre. Varieties differ materially in size of seed, and a widely branching variety like Refugee may be spaced more sparsely than some others.[8] Gillis (*Am. Soc. Hort. Sci. Proc.*, *25*:80) found maximum yields at stands of 6 to 9 plants per foot, but differences in yield were not nearly as great as differences in stand. The cost of seed increased rapidly with heavy sowing, so that, allowing for the factors mentioned above, a stand of 4 to 6 plants per foot is good under most conditions. Seeding should usually be at a rate somewhat above the expected stand. Limas and pole beans are sowed about half as thick.

Seed treatment with a mixture of lindane and arasan, sold as I-D, has proved valuable insurance toward a good stand, especially with limas.

Inoculation is seldom necessary since the proper bacteria for beans are almost always present.

Later Care

Training. Pole beans are sometimes allowed to climb tepee-like arrangements of poles 3 or 4 feet apart at the ground and tied together at the top. One of the best methods of training is

to support a taut wire on poles, anchoring it at the ends of the rows. A light wire is strung near the ground, and twine is strung between the wires, zigzag fashion. One top wire can serve two rows of beans or, in the home garden, a row of tomatoes and a row of beans.

FIG. 21.6. Pipe-post, wire, and string trellis for pole beans in home gardens which give longer picking season than bush beans.

For weed control, pre-emergence spray with water-soluble dinitro is suggested, applied over the total area, or in an 8- to 12-inch strip over the rows, adjusting the rate accordingly. It is not effective against perennial weeds and grasses.

Irrigation. The Blue Lake pole beans of the west are usually irrigated by furrow or by rotary sprinklers. Overwatering before germination has been completed favors disease damage to seed and shoot. Fields should be thoroughly and deeply irrigated before planting. Water is applied as seedlings come up, without wetting the tops of beds which would favor the sprouting of weed seeds. Watering after blossoming begins is heavy.

Diseases and Insects

Bacterial blight, caused by *Pseudomonas phaseoli* and other bacteria, affects chiefly the leaves of beans but may also damage the stems and pods. It winters over in the seed and refuse and spreads freely, entering the plant at any point. It may be present in seed without the appearance of any symptom. Spraying, dusting, and seed treatment are ineffectual. The only control is to procure seed from such uninfested areas as Idaho and California.

Anthracnose is caused by *Colletotrichum lindemuthianum,* which winters in seed and in bean refuse. It affects the veins on the underside of the leaves and causes sunken cankers on pods. Seeds may be discolored. Control is by procuring seed grown in disease-free areas of the west. The disease is more serious in wet weather. Plantings should not be cultivated when wet, as tools carry infection. Anthracnose-resistant strains are available.

Mosaic, a virus disease, results in characteristic mottling and malformation of plants. Garden varieties of beans are little troubled, but Refugee is highly susceptible. However, resistant strains are now available.

Mexican bean beetle, *Epilachna varivestis,* has long been troublesome in the west. It was discovered in Alabama in 1920 and has since spread to practically the entire area east of the Mississippi and north of mid-Georgia. The beetle is a large ladybug, about ¼ to ⅓ inch long, seal brown in color, with eight black spots. Adults winter on rubbish and weeds. They lay yellow eggs in clusters beneath the leaves. Larvae are yellow, bristly fellows that feed from the under sides of the leaves, devastating the foliage in irregular patches and leaving veins in a lacy pattern. Rotenone or parathion dusts or sprays are both effective if applied at the proper time and to cover the underside of leaves.

Bean weevil. See pea weevil, above.

Seed corn maggot, *Hylemyia cilicrura,* lays eggs in the soil, and larvae or maggots attack germinating beans, often destroying the plumule or central bud and resulting in plants that are variously called blinds, snakeheads, or baldheads. Early preparation of the soil, thorough plowing under of refuse, shallow planting, and avoidance of planting in cold, wet weather are helpful. Treating the seed with a mixture of insecticide (chlor-

dane or lindane) and fungicide (arasan or captan) plus a sticker has given excellent control. It is sold as I-D.

Marketing

Beans for processing are picked by hand, large gangs of workers often being assembled by a padrone or labor contractor. Picking machines are coming into use for factory beans.

Beans for market are picked in the same way and are usually sent to market in bushel hampers. Most of the beans from large plantings are run over a belt for sorting. Precooling is less important for beans than for peas.

Concerning Beans

Snap beans are low in calorie rating and rank neither high nor low in other nutritive values. Lima beans are high in vitamin C and are the best source of protein among the fresh vegetables. Snap beans are usually snapped, boiled, and served. Young pods are often canned or frozen whole. Sometimes whole beans are pickled or used in salads.

Botany

Classification. Beans are more various in botanical relationships than peas, as indicated by the following partial list:

Snap beans and dry beans, bush and pole—*Phaseolus vulgaris.*
Large Limas—*P. limensis*
Small Limas or Sievas—*P. lunatus.*
White Runner and Scarlet Runner—*P coccineus.*
Cowpea (really a bean)—*Vigna sinensis.*
Broad Windsor or horse bean—*Vicia faba.*
Soybean—*Glycine max.*

Root system. Beans germinate vigorously; the cotyledons push strongly through the soil. Several seedlings together may lift a hand's-breadth of crusted earth. The root system is fine rather than coarse and is marked by a deep tap root and by wide and thorough penetration in the upper soil.

Seeds. Food reserves are in the large fleshy cotyledons; the endosperm has been absorbed by the embryo before the seed matures. The embryo is then well advanced in growth and dif-

ferentiation, as evidenced by the large plumule with clearly developed leaves and the prominent radicle.

Breeding

Beans are largely self-pollinated, although some crossing occurs. Calvin N. Keeney of LeRoy, N. Y., about 1885, found a plant of the Refugee bean bearing stringless pods. He propagated this, and the result was Stringless Green Refugee. This was crossed by Mr. Keeney and others with many additional varieties so that the planting of stringy sorts is today wholly unnecessary. Modern breeding has given us higher quality, greater uniformity and productiveness, and, in some varieties, resistance to mosaic and anthracnose with some tolerance to bacterial blight.

Seed production

Seed is produced chiefly in California, Idaho, and other western states where freedom from certain diseases and good ripening and curing conditions prevail.

Importance

Snap beans (not including Limas or dry beans) rank seventh in value of product among the vegetables. The crop averaged $43,000,000 in value in 1951 and 1952. Beans for fresh market involve about 57% of the total acreage.

Florida plants over a third of the acreage of beans for fresh market, 60,000 acres in 1952. The Carolinas and New York follow. The principal states producing for processing are New York, Wisconsin, Maryland, and Florida.

Yields and costs

The average yield of snap beans for the country is just over 85 bushels per acre (30 pounds per bushel). California's late crop, however, triples this. For processing, the average yield is about 2 tons per acre. Oregon reports 8 tons, largely of Blue Lake pole beans which sometimes yield 10 to 12 tons per acre.

History

There is no record of the culture of beans prior to the voyages of Columbus. Evidence found in ancient new world tombs has revealed many types and indications of long-established culture.

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22

Vine Crops

The five principal vine crops are muskmelons or cantaloupes,* watermelons, cucumbers, squash, and pumpkins. The gourds also belong to this family.

In several respects these five crop plants are much alike. All possess a trailing or vining habit except for a few varieties which have been bred as bush types. This merely means that internodes are short. None of them withstands frost. All are insect pollinated. On the other hand these crop plants differ widely in use. The cucumber is used for salad and pickles, the muskmelon and watermelon for breakfast or dessert, and the squash and pumpkins for cooked vegetables and pies. They also differ in temperature tolerance and requirement. The cucumber grows quickly and thrives in relatively cool climates and seasons. The watermelon requires a long, warm season. The watermelon is more resistant to drouth than others. These crops thrive in a wide variety of soils but generally do best in the lighter types They are subject to many of the same insects and diseases.

Muskmelon or cantaloupe is selected as the type crop for full discussion, and other crops will be related to it.

MUSKMELON OR CANTALOUPE

Muskmelons are at their best in moderately sandy soil, and they show highest quality when they can mature under warm, sunny conditions. They require a slightly longer season than cucumbers, but not so long as most watermelons. The great commercial areas are in Arizona, California, Colorado, and east

* In the United States these terms are practically synonymous, muskmelon being more used in the northeast, cantaloupe more commonly elsewhere and on the markets. Strictly the word cantaloupe should be reserved for the species *Cucumis cantalupensis*, seldom grown in the United States.

to New Jersey and North Carolina, but they are successfully grown for local market as far north as Minnesota, Michigan, and New York.

As with all the cucurbits, weedy hedges, headlands, and neighboring fields should be either avoided or cleaned up as they frequently harbor striped beetles, squash bugs, mosaic diseases, and other enemies.

Soil Management

Muskmelons, like other vine crops, respond well to stable manure, and soil should be well enriched. The old practice of

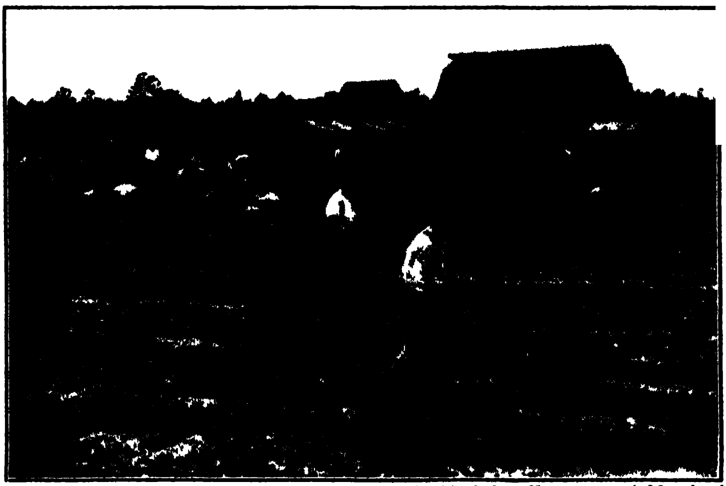

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FIG. 221 A 50-acre field of muskmelons on the eastern shore of Maryland.

burying manure in hills or furrows is now generally obsolete in commercial practice and is unnecessary in the home garden. There is no advantage in having a raised hill, unless drainage is poor. Muskmelons do not thrive on acid soils, the suggested *p*H range being 6.0–6.7.

Fertilizer treatments are too varied among crops and regions to justify a general statement; it is well to consult local recommendations. The rates of application are not usually heavy, say 40 to 80 pounds each of nitrogen and potash and twice as much

phosphorus, or 400 to 800 pounds per acre of a 5–10–5 will serve as a starting point in the absence of better advice or until experience has been gained.

Varieties

Hale Best, of which there are many strains, far outstrips all other muskmelon varieties in importance. It is small to medium in size, nearly round, only slightly ribbed, very closely and deeply netted, of good rind for shipping, with thick orange flesh of high quality. **Resistant No. 45** is resistant to one strain of powdery mildew. Other resistant strains have been developed, including **PMR5.**

Bender is a vigorous grower, producing fruits that are nearly round, gray-green in color, sparsely netted, with thick orange flesh, and of medium to high but variable quality. **Seneca Bender** is a smaller and more uniform strain for crate packing. **Delicious** resembles Bender but is earlier, smaller, and better netted.

Iroquois, similar to Bender, and **Delicious 51** are resistant to fusarium. Iroquois has taken over much of the Bender acreage.

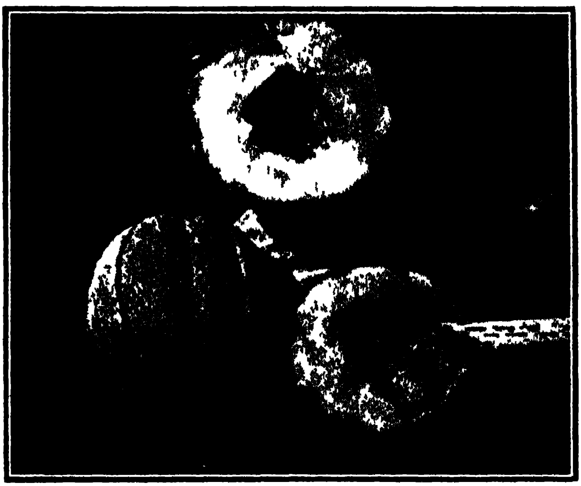

Fig. 22.2. Iroquois, a high quality, fusarium-resistant muskmelon.

Pride of Wisconsin and similar varieties are widely grown in the northeast. Vines are strong, fruits of medium size, thick flesh, firm rind and high quality, but with a tendency to crack in rainy weather. **Harvest Queen** is a fusarium wilt-resistant variety similar to Pride of Wisconsin.

Honey Rock and **Hearts of Gold** are important in northern Ohio and Indiana and southern Michigan, with thick orange flesh and of high quality. They have firm rind and are good for shipping.

Honey Dew is marked by a smooth, unnetted, light green rind, and thick, white flesh. It is very sweet but lacking the characteristic muskmelon flavor. Melons are large and late in maturing. **Casaba** and **Persian** are late varieties of the southwest Casaba is very rough in surface; Persian is closely netted.

Plant Growing

Most vine crops are seeded directly in the garden or field, but a considerable number of muskmelons, especially in the north, are started under glass for early maturity. The same methods may be used for summer squash, cucumbers, and watermelons. These plants, as found by Loomis (see page 146), do not readily recover from transplanting, and so the procedure is different from that for tomatoes and cabbage.

Plants are sometimes started in greenhouses and moved out to cold frames or mild hotbeds, or they may be grown entirely in hotbeds, the heat being allowed to decline as the time for field setting approaches.

Seed is commonly sowed in good plant-growing soil (Chapter 9) in veneer or paper bands, berry boxes, paper pots, or clay pots, of 2- to 4-inch size. Seed should not be started too soon, about 3 weeks or a month before field setting. If too much time is allowed, plants begin to vine and are hard to handle, also they may be stunted and checked so that they do not start readily. Two or three seeds are planted in each container; when germination is complete, the plants are thinned to one per pot. The temperature should be rather warm, 65° to 75° F., and watering should be judicious and moderate, gauged to bring slow, steady, unchecked growth and full development of a strong root system. Plants that are 5 to 7 inches high at field setting are big enough. See Fig. 22.3.

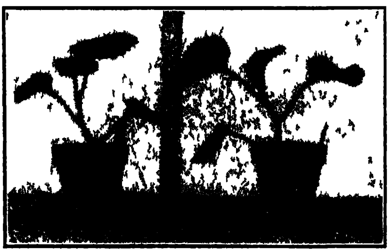

FIG. 22.3 Plants of the vine crops for transplanting should not be allowed to grow too large. These are about right.

Planting

When to plant. Muskmelons in common with all the vine crops will not stand frost. When soil and weather are cold and wet, young plants do not thrive, and seeds do not germinate well and may rot in the ground. If planted too soon, seeds may receive a check from which they will recover but slowly. Thus plants should not be set until danger of frost is past, about tomato-setting time or a few days later. Seed may be sowed, say, a week earlier. Seed should usually be treated with bichloride of mercury and then with arasan, according to local experience, for control of diseases.

Spacing. Most people in home and commercial practice have too many plants per acre. It is usual for commercial growers

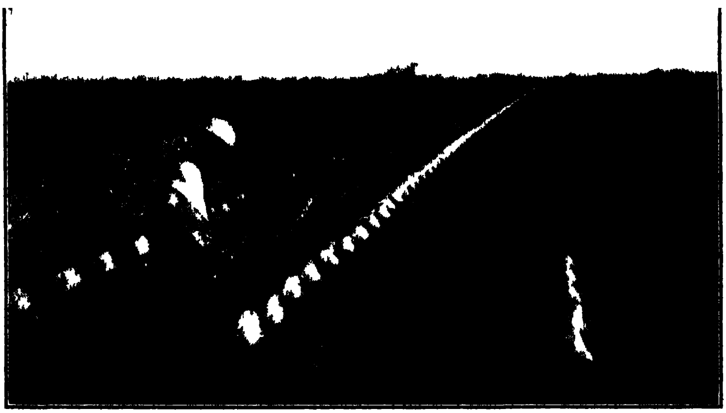

Fig 224 Muskmelons, first early crop, are sheltered with great care and expense in Imperial Valley Note the posts, wire, Kraft paper, and brush on north side of ridged rows Hills are further protected with paper caps.

to thin to one plant per place. It is well to have plants closer within the row than to have the same spacing both ways; thus, 4 by 6 feet is better than 5 by 5 feet. This spacing facilitates cultivation and reduces damage to vines during picking. Muskmelons are sometimes sowed sparsely in drills, being thinned later to the spacings suggested.

Covering varies from ½ to 1 inch according to soil conditions, deeper in drier and sandier soils. The quantity of seed per acre varies with conditions, but 1½ to 2½ pounds per acre is sug-

gested as a rough guide. Heavier sowing is needed if soil conditions are unfavorable, or if plantings are made very early. Such heavy sowing should be followed by heartless and relentless thinning after the plants are well established. It is safer to do the thinning two or three times rather than all at once.

Plant protectors are more extensively used for muskmelons than for any other crop, either for seed or transplanted plants (page 238). In California, especially in Imperial Valley, protectors for the early crops are supplemented by elaborate windbreaks of posts, wire, brush, and paper. See Fig. 22.4.

Cultural Methods

Cultivation. If weeds are controlled early, there should be little trouble later, as well-grown plants cover the ground fully. The root system is shallow, and deep cultivation should be avoided. Some hand pulling of weeds may be necessary to avoid a weedy field at harvest time and to prevent reseeding of the land. Where rows are widely spaced, a cover crop such as cowpeas or ladino clover or rye may be planted at the last cultivation.

A new herbicide, phthalamic acid (Alanap), has shown promise for weed control among cucurbits.

Irrigated melons are usually planted on the south side of beds laid out 6 or 7 feet center to center, and just above irrigation water level. Pre-irrigation is good practice. Then it is well to delay further irrigation for some time so that the root system may develop well. Thereafter water is applied lightly and frequently rather than heavily and often, the requirement increasing as plants develop. Careful watching of plants and soil is necessary to guide in application of water. Color and growth of vines tell the story, but no writer has been able to make a specific set of directions.

Diseases

Bacterial wilt, caused by *Erwinea tracheiphila,* attacks the vine crops, except watermelon. The bacteria winter over in the bodies of striped beetles which then infect the plants. The organism multiplies in the stems, clogging the water vessels and

causing wilting. Persistent dusting against the beetles, usually with rotenone, is the only effective method of control.

Mosaic, a virus disease, affects cucumbers, muskmelons, and squash. It gives rise to white pickle of cucumbers, a sunken mottling of the fruit with contrasting light and dark green areas. The disease is harbored in many weeds, wild cucumbers, milkweed, catnip, poke berry, ground cherry, and others. It is carried by aphids and the striped beetle. Weed control, insect control, and use of resistant varieties, so far as they have been developed, are helpful measures. Pulling of infected plants may be useful during early stages of growth but is ineffective later.

Angular leaf spot caused by *Pseudomonas lachrymans*, **anthracnose,** by *Colletotrichum lagenarium*, and **scab,** by *Cladosporium cucumerinum*, occur on various vine crops. Anthracnose is very serious in some watermelon areas. Seed treatment with bichloride of mercury or with arasan is recommended. Carbamate dust or spray gives good control.

Powdery mildew, caused by *Erysiphe cichoracearum*, is an especially serious enemy of muskmelons but affects other vine crops as well. The fungus growth on the upper sides of the leaves is mealy in appearance. Resistant varieties have been bred for use in the southwest. PMR 45 and PMR 5 resist some but not all strains of the fungus.

Downy mildew, caused by *Pseudoperonospora cubensis*, is less prevalent than powdery mildew and is serious during warm humid weather. Some resistant strains have been developed. Carbamate sprays are of some service.

Chlorosis. Muskmelons frequently show discoloration of leaves; yellowing may be general, or at the margins, or in areas between veins. This may be caused by copper injury, soil acidity, drouth, and perhaps shortage of one or another of the major or minor essential nutrients, as well as by virus disease.

Insects

Striped cucumber beetle, *Diabrotica vittata*, is a serious enemy of the vine crops, especially in their early growth, damaging the plants and carrying the bacterial wilt and mosaic or virus diseases. The adult is about ¼ inch long and is yellowish green with pronounced black stripes. Control is by faithful early

dusting with materials carrying rotenone or parathion or methoxychlor. Carbamate sprays are of some service.

Melon aphis, *Aphis gossypii*, damages vine crops in much the same way as other plants. Dusting with nicotine or parathion dust is the usual control. A long cloth or canvas apron behind the duster adds to the effectiveness in large fields. On a small scale, a sheet metal cone on the duster tube may be held in place for a few seconds over each plant. This is also good practice for striped beetles.

Nematodes, *Heterodera radicicola*, cause serious losses in vine crops. No direct control is feasible; the best measures are to use newly cleared land or to adopt a crop rotation which includes non-susceptible crops.

Harvesting and Marketing

Quality in muskmelons consists of several elements: color of flesh, deep orange preferred; thickness of flesh; texture of flesh, juicy and smooth and not fibrous with a moderate degree of softening; characteristic aromatic flavor; sweetness.

High quality is dependent upon three principal factors: full healthy foliage, full maturity, and warm, sunny weather.

Changes in ripening.[4] Rosa[4d] found that melons, in ripening on the vine, increased in total sugar content; reducing sugars, dextrose (glucose), and levulose declined, but sucrose (cane sugar) gained until it more than overbalanced. The increase in total sugars continued until full maturity. Softening is traceable to changes from insoluble to soluble forms of pectin.*

There was little or no gain in sugar when immature fruits were picked and stored, but softening proceeded normally. Chace, Church, and Denny[4c] stated that flavor improves after picking, but they did not say what chemical compound is responsible for the characteristic flavor.

Some states require that melons shall not be shipped unless the content of soluble solids in expressed juice represents 8 to 10%. This value is determined by means of a Brix spindle, a form of hydrometer (not to be confused with hygrometer), with scale set for percentage of soluble solids, estimated as sucrose.

* Pectins are rather complex colloidal carbohydrates which are important as cementing material between cells and are also useful in jelly-making.

As soluble solids consist largely of sugar, this value is a good measure of maturity.

Judging maturity. Experienced harvesters recognize market maturity in muskmelons by color and appearance of netting. The green color between nets gradually changes to yellow in most varieties. Another useful test is the parting of the stem or pedicel from the fruit. If parting is complete and easy, leaving a circular depression or scar, the melon is mature and is

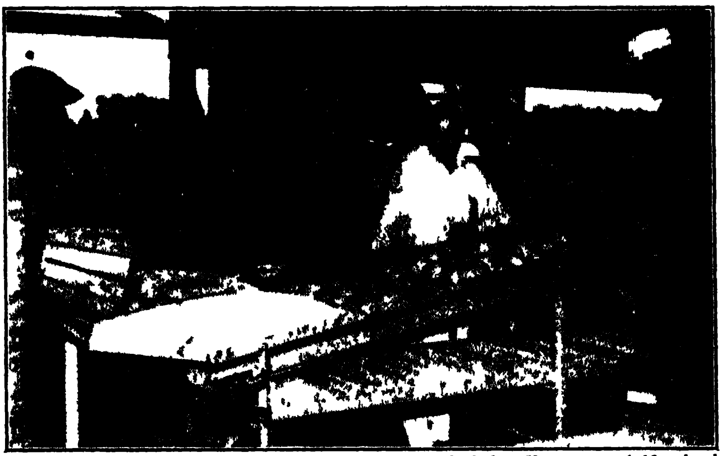

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FIG 225 Melons sorted for culls before going over sizing machine

said to be at *full slip*. *Half slip* designates a stage when the stem adheres to half the scar. Some varieties are not ready for the table until a day or two after full-slip stage. Melons are often picked too soon in order to forestall over-softening before they are sold, but quality is sacrificed by this practice. For a good discussion of these factors, see refs. 4 and 5

Handling. In commercial shipping areas, muskmelons are picked, sorted, and centrally packed in crates designed to carry 45 fruits. Jumbo, standard, and pony crates are made for various sizes, but sometimes large melons are packed 36 per crate or in flat crates.

In the areas east of the Mississippi, muskmelons are not commonly picked or handled as carefully as they should be. Sizing and orderly packing are just now becoming common practice.

(See Fig. 22.5.) Many low-quality melons that are poorly ripened or come from diseased vines are marketed, thus undermining the popularity of an excellent product. Some growers have built a special trade founded on a quality product.

Yield. The average yield of muskmelons is about 115 crates (approximately 60 pounds each) per acre. The averages for important states range from 50 or 60 in the south to more than 160 crates per acre in the west.

WATERMELON

The watermelon requires a long, warm season, and its culture is general throughout the south from Florida and Georgia to California. It does well in New Jersey and the middle western states and can be grown for local market and home use in New York, Michigan, and Wisconsin. New early varieties of high quality justify more attention than has been given in the past to watermelon culture in the north.

The watermelon like other vine crops will not tolerate frost, but it is more resistant to drouth than most of its cousins. Curi-

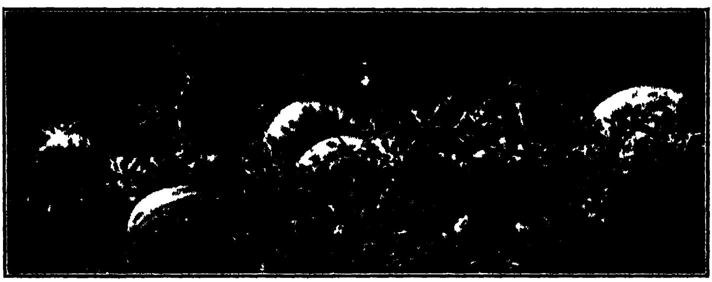

FIG. 22.6. The watermelon is a great southern crop, but newer, early varieties offer both high quality and successful production in the north. This is Early Kansas.

ously enough the watermelon is not so high in water content (92%) as asparagus (93%), celery (94%), cucumber (96%), or lettuce (95%).

Commercial watermelon crops are usually grown on sandy soil, and newly cleared lands are favored. The watermelon tolerates rather acid soil in contrast to the muskmelon.

Soil Management

In respect to soil management and fertilization the same general principles are applicable for watermelons as for muskmelons.

Varieties

Dixie Queen or **Cuban Queen** is a short elliptical watermelon, sharply striped, somewhat granular in flesh, but very sweet. Fusarium-resistant strains are available. **Black Diamond** and **Stone Mountain** or **Dixie Belle** are similar but not striped.

Tom Watson is a shipping variety, of medium quality, elongated in form and dark green in color.

Congo is anthracnose resistant and makes excellent growth and yield. Melons are of medium size, oblong, striped, with firm thin rind and excellent quality. This new variety has come rapidly into high popularity as a shipper from the south.

Kleckley is very popular as a high-quality variety for home use and local market. It is long, dark green, and somewhat similar to Tom Watson in appearance but a distinct variety. **Leesburg** is a fusarium-resistant strain developed in Florida. **Pride of Muscatine** was developed in Iowa.

Klondike is the leading watermelon of the far west, of small to medium size, elliptical, dark green or striped, and of excellent quality in juiciness, sweetness, flavor, and crispness of texture. The rind is thin and rather tender, varying somewhat among the various strains, of which there are several. Why it is not grown in the east is not clear except that it breaks easily. The size is much more convenient than that of the large eastern varieties.

Early Kansas is earlier than Dixie Queen, short, oval, striped, of medium size, and fine quality. **Early Arizona** is solid green and of fine quality.

Honey Cream is very early, small, round, striped, of tender rind. The flesh is yellow, and the seeds are small. This is one of the best-quality melons in existence. It is as early as most varieties of muskmelon—maturity is 80 to 85 days—and so is well adapted for the north.

New Hampshire Midget is a very small, very early, prolific variety that does well in northern summers. It passes best maturity quickly.

Rhode Island Red is a new red-fleshed, round-striped melon for northern culture.

Breeding and promotion of small watermelons are needed to obviate the unsanitary and inconvenient practice of cutting melons in stores.

The Japanese have produced hybrid strains of seedless watermelons. One parent is a tetraploid (referring to chromosome number) produced by colchicine treatment, the other a normal diploid. Progeny is a sterile triploid. Seed is expensive, germi-

nation is difficult, and a few plants of normal varieties are required for pollination. The advantages are not conspicuous.

PLANTING

Watermelon seed may be planted at about the same time as muskmelon, but spacing is much wider. Usually the spacing is 80 to 120 square feet per plant or per hill, the spacing between rows being somewhat wider than the spacing in the rows, say 8 by 10 to 10 by 12 feet. Small-growing early watermelons may be planted more closely, but in general wide spacing for this crop has been supported by experimental results. About 2 to 4 pounds of seed is required per acre. Plant protectors are effective for this crop.

CULTURAL PRACTICES

Weed control is managed as with other vine crops. Phthalamic acid (Alanap) is promising for chemical control.

Thinning fruits. Watermelon fruits are sometimes removed, leaving one or two per plant to give better size. Present-day markets are inclining toward smaller melons, and experiments by Woodard (*Ga. Coastal Plain Sta. Bul.* 18) support the idea of thinning only to remove ill-shaped fruits. Pruning of vines is not to be recommended.

Irrigation is the same as with muskmelons.

Diseases and insects. See muskmelons.

HARVESTING AND MARKETING

In the early 1900's, Horace Roberts of New Jersey used to paste a label on each watermelon which read: "Guaranteed, Horace Roberts." That meant that, if the melon was not good, the buyer got another. Mr. Roberts knew how to pick melons. He did not use any formal test. He just looked at them.

When is a watermelon ripe? The novice is deeply puzzled about how to recognize a ripe watermelon. The following hints are offered.

1. *Thumping.* A dead flat sound for ripe watermelons; a sharp ringing sound for green.

2. *Tendril or curlicue dead.* The melon is seldom ripe if the tendril is still green; it may be unripe if the tendril is dried up.

3. *Color of belly or ground spot.* Usually changes from greenish white to yellow on ripening.

4. *Pressure on the melon.* A ripe one crackles within. Not very dependable and damages melons. Also the rind of a ripe melon, especially a thin-skinned one, yields a little under thumb pressure.

5. *Plugging or cutting* a little pyramid of rind and flesh is a sure test but it ruins the melon for market.

Varieties vary in their signs of ripeness. A green melon may give a flat sound if it is hollow, which is a defect rather common in the Dixie Queen group. Honey Cream is very crisp and turgid and may give a sharp sound when ripe. The only real estimate of ripeness comes from close observation and experience.

Wait until watermelons are ripe. Many retail buyers of watermelons become disgusted with quality early in the season because growers are so anxious to get them off before the price drops that they pick them green. Also poor supervision and employment of careless or untrained workers result in many unripe melons being shipped. This cuts demand and undermines prices. The customer who gets a couple of bad melons at the beginning of the season fails to buy later, when practically all are good. The watermelon ripens very little on the way to market.

Treat the stems. Watermelons should be cut with a long stem rather than pulled. When they are loaded, the stem is cut again and treated with a starch paste, containing copper sulfate, as a precaution against stem rot (*Diplodia*) which may develop in transit. A gallon of paste is made by bringing 3½ quarts of water and 8 ounces of copper sulfate to a boil. Then 8 ounces of laundry starch that has been stirred smooth with a pint of water is added. The paste should be used fresh and applied with a brush to the recut stem as the car or truck is loaded.

Mechanical injury to watermelons due to careless handling is common and occasions losses that are not seen by the grower. They appear at the market, and the shipper wonders why he did not get good returns. Standing melons on end, piling them too high, and allowing them to lie in the field, especially ground

side up, are all damaging. Trucks should be bedded with straw, and sides should be padded. One nail or bolt sticking out a half inch or less may damage many melons in a season. Nor should melons be loaded more than five deep.

Loading. The watermelon is one of the last remaining vegetables to be handled in bulk. A carload of 20-pound melons is about 1,400 melons; of 25-pound, 1,000 melons; and of 30-pound, 750 melons.

Watermelons are shipped in various kinds of railroad cars. Floors are bedded with straw, excelsior, or pine straw. The sides of the cars are papered, and the ends are padded with special excelsior and paper quilts The cars should be well cleaned, for salt, fertilizer, and other materials are injurious to melons in transit. Melons are loaded securely, in orderly fashion, in layers and stacks to prevent shifting and breakage in transit. Small "icebox" watermelons are now being shipped in crates.

Yields. The national average yield of watermelons is about 260 melons per acre, western states showing over 500 per acre.

CUCUMBERS

Cucumbers thrive in a wide variety of soils ranging from sandy to moderately heavy. They mature in a relatively short season and do not require as warm a climate as watermelon.

Soil Management

See muskmelons.

Varieties

Cucumber varieties are classified as slicers or table stock and picklers. Slicers should be shapely and round-ended, 7 or 8 inches long, and of a very dark and persistent green color. Pickling varieties are shorter and very prolific; they are used principally for small pickles. Slicers are often pickled, when they are somewhat immature, for dills or larger pickles.

Marketer is the leading slicing cucumber save where disease requires use of a resistant variety. The vine is vigorous and prolific. It is long, slightly tapering at the ends, well colored to the end, and with small seed space.

FIG 22 7 Marketer is the leading slicing cucumber.

A & C, Straight Eight, and **Colorado** are about 8 inches long, well filled at the ends, smooth, of fine, dark color, and widely grown for home and market.

Burpee Hybrid is outstanding for vigor of vines and heavy yield. Fruit color is not as good as Marketer

Santee is resistant to downy mildew, and **Niagara** to mosaic.

National Pickling is a leading pickling variety. **MR17** and **Yorkstate Pickling** are similar and resistant to mosaic

Planting

Cucumbers should not be planted to be above ground until danger of frost is past. Rows are usually 4 to 5 feet apart, and single plants 3 or 4 feet apart in the rows. Home gardeners often have cucumbers much too thick. In commercial pickle fields close planting does not materially increase the yields and greatly increases the difficulty of finding the cucumbers, thus increasing the cost of picking. Sowing seed sparsely in drills and thinning to 2 to 4 feet apart in the row is good practice. The seed should be covered 1 to 1½ inches according to soil conditions. Two to 3 pounds of seed is sufficient for an acre.

Cultural Methods

Cultivation, weed control, and irrigation are handled as with muskmelons.

Diseases and Insects

See muskmelon.

Harvesting and Marketing

Cucumbers for market are usually taken when they have reached somewhat less than full diameter but when their surface has smoothed out considerably. Seeds are still small and soft. The usual package is the bushel basket, but hampers are also used.

Washing or brushing, sorting, and waxing of cucumbers in central packing plants are becoming common practices. Waxing enhances appearance and retards evaporation. See ref. 9 of Chapter 4.

For pickling, maturity of cucumbers is judged by size. Small pickles are often sold by count or designated by count per bushel. Manufacturers buy by the bushel or 100 pounds, setting different prices for different size limits. For example, Seaton[12] reports a Michigan standard: small, 1¾ to 3¼ inches long; large, 3¼ to 5½ inches. He found that picking at three- to four-day intervals was most profitable for the grower; that more frequent picking increased the number of fruits harvested per plant but not sufficiently to justify the extra labor of frequent gathering. Seaton's bulletin contains a good analysis of the factors governing the balance of size, price, and net return per acre.

Pickling cucumbers. The cucumber is the most important of the vegetables from the standpoint of both commercial and home preservation by pickling.

Pickling is defined by Joslyn and Cruess (*Calif. Ext. Cir.* 37) as "preservation of food in brine or vinegar, either with or without lactic acid fermentation." This reference furnishes a good brief treatise on principles and practice of pickling. Most cucumber pickles are made by fermenting the cucumbers with salt. This fermentation is brought about in vats or barrels by lactic acid bacteria, *Lactobacillus* spp., which are everywhere present and which thrive in a concentration of salt and acid that prevents development of spoilage organisms. After fermentation proceeds for a time, acidity reaches a level that kills the bacteria. Dill pickles are fermented in the presence of the herb dill and other spices and are not treated further. Fermented pickles may be soaked and washed for removal of most of the salt, and then they may be made into sour pickles, sweet pickles, spiced

pickles, and others, with or without cooking. Some pickles are made without fermentation.

Yield of cucumbers for market is about 150 bushels per acre, and for pickling it is about 80 bushels per acre. Good yields are higher than this.

SQUASH AND PUMPKIN

The terms squash and pumpkin are rather sadly confused. Strictly, squash is *Cucurbita maxima*, including principally Hubbard, and other thick-stemmed winter varieties. Such late squash as Table Queen and Delicata are really pumpkins, *C. pepo,* as is evidenced by their slender ridged stems, as well as by other characters. The same is also true of the summer squash, whether Bush Scallop, Straightneck, or Zucchini. The winter crookneck squash or cushaws, Butternut, and also Large Cheese and Tennessee Sweet Potato, belong to *C. moschata,* which is more closely related to *C. pepo* than to *C. maxima* (*Iowa Sta. Bul.* 244). See ref. 1, which proposes another species, *C. mixta.*

Summer squash are grown in all parts of the United States, and they will mature in the far north under conditions suitable for cucumbers. The summer squash is important commercially in Florida and very popular in California. Winter squash are grown chiefly in the northern half of the United States. The cushaws are grown chiefly in the south, and the pumpkins almost everywhere.

Soil Management

Squash and pumpkin do well in soils ranging about as widely as for cucumbers. Management is the same as for muskmelons and cucumbers.

Varieties

Varieties of winter squash

Green Hubbard, a very old variety, has long vigorous vines and coarse leaves. Fruits are of medium size, usually 8 to 16 pounds, the body being nearly globular but with lobes or projections at the ends. The color is an ashy green with whitish, irregular stripes. The surface is slightly roughened. **Warted Hubbard** has a much rougher surface. **Golden Hubbard** and **Boston Marrow** are of golden orange color and similar in type. Boston

Marrow, which is earlier, is popular for commercial canning. **Quality, Delicious,** and **Golden Delicious** are smaller than the others and considered of high quality.

Blue Hubbard is very large, vigorous, with prominent lobes at both ends, coarsely warted, of gray-green color, thick-fleshed, and of good keeping quality. It is now the leading northeastern commercial variety.

Essex Hybrid and **Bay State** are turban-shaped squash of good size, orange and green, respectively. They are prized in New England for high quality. **Buttercup** is a small turban squash that was bred by A. F. Yeager, then of North Dakota Agricultural College. It is considered one of the highest quality squashes available.

Butternut, cushaw (*C. moschata*), is an old New England variety, now revived to considerable popularity. It grows vigorously and yields well of squashes weighing 2 to 4 pounds, bulbous, with heavy neck, tan or buff in color. Seed cavity is small, and flesh is of high quality.

Varieties of summer squash

Summer squash should properly be called summer pumpkin as they belong to *C. pepo,* but an effort to establish correct usage some years ago failed. Several hybrids are now available.

Straightneck is successor to the old Summer Crooknecks. There are several strains, **Giant, Early Prolific,** and **Connecticut,** differing in minor characters. Vines are of bush type, that is with short internodes. Flesh is moderately thick, somewhat watery in consistency, and so mild and delicate in flavor that some people scorn the vegetable. **Yankee Hybrid,** developed by L. C. Curtis of the Connecticut Experiment Station, is an improved strain, a hybrid from inbreds. It is smooth, shapely, early, and prolific.

White Bush Scallop or **Pattypan** appears in various strains. In general the squashes are flat, with ten distinct lobes around the edge. These are used young, and the flesh is of about the same quality as Straightneck. There is also a **Yellow Bush Scallop.**

Cocozelle is a bush squash, elongated, almost the shape of a large cucumber. The skin is dark green with light stripes. The quality is similar to that of other summer squash. **Zucchini** is very dark green without stripes.

Varieties of pumpkin

Connecticut Field is the common cornfield, Hallowe'en, or pie pumpkin. The vine is large and vigorous. Fruits vary in shape from flattened to deep drum-shaped, weighing from 5 to 30 pounds or more on occasion. Stocks are decidedly lacking in uniformity.

Small Sugar or **New England Pie, Winter Luxury,** and **Golden Oblong** are small pumpkins of differing characters, and of better quality than field varieties.

Table Queen, also known as Des Moines and Acorn, is called squash but is really a pumpkin. It is about 6 inches long, egg shaped, pointed at the blossom end, sharply ribbed, and of dark, glossy, green color. The flesh is of medium thickness, light yellow in color, of fine but not very uniform quality. It is very prolific and keeps well. **Delicata and Fordhook** are also small baking squash.

Planting

Summer squash, most of which have dwarf or bushy plants, require about the same spacing as cucumbers or muskmelons. Large-growing squash and pumpkins are spaced about like watermelon.

Cultivation, weed control, and irrigation are managed as with other vine crops.

Diseases and Insects

See muskmelons.

The squash bug, or stink bug, **Anasa tristis,** is troublesome, especially in small plantings. Hand picking and trapping under a board laid on the ground is practical on a small scale. Rotenone and pyrethrins are of some value.

Squash vine borer, *Melittia satyriniformis.* Crop rotation, planting summer squash as an early trap-crop, slitting the stem with a knife to slay the beast, and the use of rotenone, nicotine, or parathion are suggested.

Harvesting and Marketing

Pumpkins and winter squash should be allowed to attain full size and maturity of seeds and rind. Hubbard squash, taken while young and soft-skinned, are very delicious when used like summer squash, as they are richer in flavor and texture than the usual varieties.

The utmost care in handling is necessary, for cuts and bruises are easily inflicted, marring the product and permitting the entrance of decay organisms. This is disastrous if late squash are to be stored. Careful growers like J. C. Richardson of Massachusetts require workers to wear cotton gloves to avoid fingernail cuts, and trucks are lined with quilts and rugs, which are also put between layers.

Summer squash are at an edible stage any time before the skin begins to harden and the seeds attain full size. On the west coast they are harvested very small, 4 to 6 inches long for Straightnecks, 3 inches in diameter for Scallops. This probably means little gain in quality over harvesting, say, at three-fourths of full size, when skin is tender, seeds immature, and yield is much greater.

Early shipments from the south are made in bushel baskets, hampers, and crates. Summer squash from the south are sometimes wrapped in tissue to safeguard against surface damage and blemishing.

Storage.[16] Late or winter squash are extensively stored, but exacting requirements must be carefully met, only well-matured fruits being stored, the stems being retained, and even the smallest mechanical injury being avoided. The storage atmosphere should be dry, under 70% relative humidity, and the temperature should be about 45° to 50° F.

Cummings and Platenius, Jamison, and Thompson (see ref 4 of Chapter 14) have shown that low storage temperature reduces losses due to shrinkage in weight. Platenius and associates found no support for the old recommendation that squash be subjected to a curing or drying period of 2 to 4 weeks at 70° to 80° F. This treatment failed to reduce susceptibility to storage rots and hastened shrinkage loss through increased respiration and evaporation. Temperatures lower than 40° F. are favorable for certain decay fungi.

CONCERNING THE VINE CROPS

Use and food value

Energy or calorie values in the cucurbits are not high, reaching medium levels only in winter squash Minerals and vitamins are relatively low except that vitamin A, derived from carotene, is high in the yellow-fleshed squash, pumpkins, and muskmelons, and vitamin C in muskmelons.

Botany

Plants of the family Cucurbitaceae are primarily tropical and subtropical in habitat although some of them are grown far into the temperate regions. Most of them are herbaceous annuals, soft stemmed, trailing, bearing tendrils. Flowers are mostly

monoecious (male and female organs in separate flowers on the same plant) or dioecious (male and female flowers on separate plants). Female flowers are recognized by the ovary below the blossom bud. Male flowers of muskmelon and watermelon are unisexual, but some varieties also bear hermaphroditic or perfect flowers—that is, with both pistil and stamens. Such plants are called andromonoecious (male-monoecious).

Flowers are tubular and bell-like, mostly yellow, some large and showy. Pollination is by insects, and crossing among plants of the same species is very general. The popular idea that there is free crossing between species and genera is unfounded. Low quality in muskmelons is not likely to be caused by crossing with some other cucurbit but rather by immaturity, unfavorable weather, and especially by diseased and dead foliage.

Breeding

Pollination is readily controlled by bagging and hand work. Apparently the phenomenon of heterosis or hybrid vigor is not highly developed in the cucurbits, though hybrid cucumbers and summer squash have been bred. There is wide variation in proportion of male and female flowers, influenced by both heredity and environment.

Breeding effort has yielded many improvements in type, edible quality, and disease resistance. Straight Eight and National Pickling cucumbers represent planned improvements in type. Niagara is mosaic resistant, combining this character with a good market type. PMR 45 is a powdery-mildew-resistant muskmelon variety resulting from a cross between Hale Best and a resistant variety of little other merit, brought from India. L. C. Curtis of Connecticut developed the Yankee Hybrid summer squash from inbred lines of Straightneck. Fusarium-resistant watermelons are available. Early, firm-rinded, small-sized watermelons of high quality have been developed. Cummings of Vermont produced a uniform strain of Hubbard squash of dry flesh character.

Seed production

The seed of the vine crops is grown largely in irrigated areas of Colorado and California. Fields of different varieties must be isolated since pollination is by insects. Large-scale recovery

of seed is by crushing fruits, washing, and screening. Some kinds are fermented, though less commonly than formerly.

HISTORY

Like maize, the pumpkin and squash, genus *Cucurbita,* are considered of new world origin, but the other vine crops are from the tropics of the old world. There seems to be no record of *Cucurbita* in Europe before the time of Columbus, and both pictures and remains—seeds and other parts—have been found in pre-Columbian graves and temples in the Americas. The primitive forms of North America were probably *C. pepo* and *C. moschata* with *C. maxima* introduced from South America perhaps 150 years ago. Erwin, in an extended quest, was unable to find pre-Columbian evidence of *C. maxima* in North America though *C. pepo* and *C. moschata* have been found in archeological surveys.

The cucumber is believed to be of African origin and to have spread early in human history to India. The muskmelon, judging by the presence of similar wild forms, is rather clearly of African origin, as is the watermelon. The watermelon has for ages been a favorite fruit of native Africans, and it was cultivated in ancient Egypt.

TO GROW LARGE FRUITS

Though large size in vegetables is not particularly desirable for home or market, there is always interest in the biggest pumpkin or biggest watermelon, and growing them is a lot of fun. There are plenty of stories about cutting the tip of the vine and letting it drink milk from a bowl. This is a myth. The main points are to give the plants a long season and favorable conditions of soil and moisture, to space plants widely, and to remove all but one fruit per vine. Hope, Ark., is famous for enormous watermelons, variety **Triumph,** weighing up to 175 pounds, which are sought for Rotary banquets, political barbecues, and Sunday-school picnics.

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23

Onion

If the boy have not a woman's gift
To rain a shower of commanded tears
An onion will do well
—SHAKESPEARE, *A Midsummer Night's Dream.*

The onion tells its own story, with pungent tang when eaten raw and with a characteristic milder flavor when cooked. It is laughed about and even ridiculed, but people like it though it brings unwanted tears and though the flavor sometimes lingers after appreciation has departed.

The onion is easily and widely grown in the home garden. It is marketed at the young, green bunching stage, or as mature bulbs.

ADAPTATION

Climate. The onion is a cool-season crop, hardy to frost but less sensitive to heat than lettuce. Rainy weather at the season when tops die down results in poor curing, rerooting, and inferior keeping quality. Driving winds, especially on muck soils, may blow the planted seed or the seedlings out of the ground or may damage plantlets by the impact of soil particles. The root system is not wide-spreading, but the onion is less sensitive to drouth than celery or lettuce.

Length of day and temperature have been found by several workers[7] (ref. 16′, Chapter 7) to have an important bearing on bulb formation in onions and upon premature formation of seed stalks (bolting). The effects differ with varieties. The Bermuda and Grano varieties, widely grown in Texas, bulb well under the rather short days of the southern winter. Varieties such as Early Yellow Globe, Brigham, and Ebenezer make good bulbs under the long days of the northern summer. See Chapter 7.

Soil. Much of the northern crop of mature dry onions is grown on muck soils, but good results are also obtained on friable sandy loams and silt loams, as in the Connecticut Valley of Massachusetts, the Laredo section of Texas, and in Colorado and California. Seedlings may not come up well in soil that crusts badly. The onion is not tolerant of high acidity, and it demands liberal fertilization. Onions are often grown in the same fields year after year, partly because weedy land is to be avoided.

SOIL MANAGEMENT

For onions on mineral soils, liberal provision for organic matter is needed to insure friability and enhance fertility. Coarse fresh stable manure should either be well covered in plowing or be applied to the previous crop and it should be free of weed seed. Green manure crops may well be planted on onion land every second or third year. If acidity is greater than about *p*H 5.5, correction by liming is probably needed.

Fertilize liberally. In general, onion soil should be liberally fertilized. Recommended analyses vary widely according to the nature of the soil and its acidity. Usually, on muck soils nitrogen content of fertilizer is relatively low and potash high. Nitrogen applications should be more liberal on acid mucks than on those near neutrality and on old mucks than on new. The value of phosphorus is generally supported by experiments. Texas results do not support heavy use of potash but most other recommendations do. For the Connecticut Valley a 1–3–2 ratio is suggested, for Virginia a 1–2–1, for Michigan muck soils a 1–3–6. Even these recommendations are subject to adjustment to requirements on various soils; hence local advice is important.

Copper for color. Knott [5] showed that thicker skin, darker color, and better keeping qualities result from the application of 200 to 300 pounds of copper sulfate per acre to copper-deficient soils, which sometimes occur as spots in fields as well as in larger blocks. The clue to this discovery was found accidentally by observing the differences in onions sprayed and unsprayed with Bordeaux on the turning lands at the ends of the rows.

Fine seedbed. Soil for onions should be well leveled and thoroughly worked down to a fine condition since seed is not

covered deeply. Any unevenness is likely to be reflected in poor stand.

VARIETIES

For green bunching onions

Green bunching onions are produced from the following:

Multiplier or **Potato onions,** *Allium cepa* var. *aggregatum,* multiply by bulb division. They are non-seeding and are not hardy in northerly climates. Bulbs are set in late summer or fall for spring harvest.

Perennial Egyptian or **Tree,** *A. cepa* var. *viviparum,* multiply by division and by the formation of bulbils on top of the central stem Blossoms develop very rarely. Bulbils are harvested in summer and reset for the next spring. They may be kept growing undisturbed for years in the home garden.

White Welsh and **Japanese,** *A. fistulosum,* are propagated by seed, are perennial in habit, and are prolific and fine-appearing onions for bunching.

Shallot, *A. ascalonicum,* divides under ground, is perennial, and is grown in Louisiana for commercial green bunch onions. The word shallot is correctly applied here but is used loosely for any green bunching onion.

For dry bulbs

Ordinary dry bulb varieties, *A. cepa,* are annual in habit but survive mild winters of the far south. They may be planted in early spring or in the south in late fall as seeds, as plants, as sets, or as small bulbs sorted from dry onions while they are being prepared for market.

Sets are bulbs that have been kept small (3/8 to 1 inch) by thick planting and crowding in the row.

A good variety of onions is smooth and symmetrical, preferably globular, not subject to doubles or splits, firm, well colored, and of good keeping quality.

Early Yellow Globe, now perhaps the leading northern variety, is nearly globular, medium yellow, a good cropper, and of good keeping quality. **Brigham Globe** was selected by Dexter Brigham of Michigan for long keeping quality as well as for desirable type. It does not sprout as readily in storage as others.

Southport Red Globe, Red Wethersfield, and **California Early Red** are leading red varieties though less important now than in the past.

Southport White Globe and **Barletta** are white varieties, used chiefly for picklers and sets.

Ebenezer is yellow, flat, and a good keeper; it is sowed widely for sets which are then planted for an early crop of mature dry bulbs.

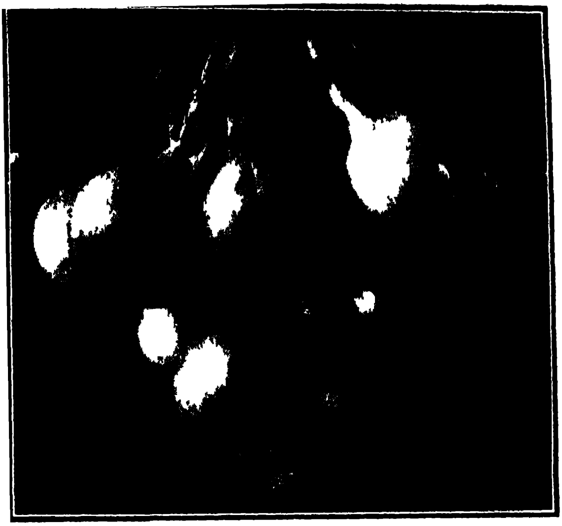

FIG. 23.1 Early Yellow Globe onions A leading northern dry bulb variety.

FIG. 23.2. Four perennial members of the onion genus. Left to right: chives, for flavoring soups and stews; Japanese Bunching; White Welsh; Egyptian or Tree. The last is propagated by bulbils which grow atop the plants.

Fig 23 3 A hybrid onion variety—Asgrow Y40

Australian Brown, a small variety grown in California, is ashy dark brown in color thick skinned strong flavored and exceptional in keeping quality

Yellow Bermuda, grown in Texas is flat thin skinned, pale yellow somewhat subject to splits and doubles mild in flavor and a poor keeper, but it is usually sold immediately on harvest The variety forms bulbs well under short-day conditions, but bulbs are poor under the long day of the northern summer **Crystal Wax** or **White Bermuda** is the white-skinned version of this variety

Utah Expt Sta

Fig 23 4 The parent bulb from which Utah White Sweet Spanish was developed

Grano or **Babosa** is early, round, pale yellow and mild flavored and is to some extent replacing the Bermudas in Texas It forms bulbs well, under both short and long days but is a poor keeper

Sweet Spanish or **Valencia** is large, round, pale to medium yellow in color, mild flavored, and of moderate keeping quality It is often grown from transplants, especially where a large size for sandwich use is desired

New hybrid varieties are being tried out and promise usefulness to commercial planters, chiefly in terms of uniformity of type and maturity and heavy yield See page 103

Leek, ***Allium porrum,*** **has leaves like the keel of a boat and does not make a round bulb.**

Chive, ***Allium schoenoprasum,*** **grows in clumps of slender shoots which are prized for flavoring purposes.**

Garlic, ***Allium sativum,*** **is flat-leaved and produces divided bulbs of distinctive flavor, widely used as a condiment.**

PLANT GROWING

Outdoor seedbeds. Most of the Texas onions, and many in other states, especially Sweet Spanish, are grown from plants started in an outdoor seedbed. Production of plants to sell is important in Texas and Arkansas.

Experiments by Hawthorn[6] have shown that growing plants in a seedbed is better than field seeding and that medium-sized ("pencil") plants are better than larger or smaller ones. Large plants give a greater proportion of splits, doubles, and seeders.

Hawthorn recommends about 20 pounds of seed per acre of plant bed, yielding about 1,000,000 plants, enough to set 12 to 15 acres at 4 by 14 to 16 inches. Rows in the plant bed are 14 to 16 inches apart, and seed is sowed in Texas and Louisiana late in September.

Under glass. In the north, seed, usually of Sweet Spanish, is sowed under glass 10 or 12 weeks before field setting, ¼ inch deep and 8 to 12 seeds per inch, with rows 2 inches apart. They are kept in a cool house (50° to 65° F.), and they are not transplanted until they go to the field.

Care is necessary to avoid overwatering, which results in over-tall, slender, weak plants. Some gardeners clip the tops a couple of weeks before field setting, but this may be harmful and should not be necessary.

PLANTING IN THE FIELD

Seed. Onion seed germinates readily and strongly but does not retain viability for many years. Seed over a year old should be tested before planting. Favorable storage conditions—cool and dry—increase its longevity.

Planting seed. Most northern dry onions are sowed directly in the field, about as early as the ground can be prepared. The plant is hardy against frost. Early sowing results in increased

yields, as the onions tend to mature at about the same time in the summer whether they have attained full growth or not. Seed is usually planted at about 4 pounds per acre when rows are about 15 inches apart. The onions withstand crowding if other conditions for growth are favorable. It is the aim to adjust the rate of seeding fairly closely, since the job of thinning is too costly to be practical. Single- or multiple-row garden drills are used.

To prevent losses in muck soils by blowing out of newly planted seeds and damage by drifting soil particles, Harmer (see ref. 3 in Chapter 10) suggests windbreaks of various sorts, planting of oats or rye between the onion rows, and irrigation. See page 159.

Planting sets. Sets are planted for green bunch onions and for dry bulbs, especially in New York and Michigan, yielding earlier onions than if seed is sown and avoiding much of the difficulty from smut. Sets are planted 2 to 3 inches apart in rows about 14 inches apart. Ebenezer is the common variety for this use.

Size of sets. It takes from 15 to 25 bushels (32 pounds per bushel) of sets per acre. Medium-sized sets, ½ to ¾ inch in diameter, are desirable. Very small sets give lower yields; large sets result in more splits, doubles, and seeders. Size of the sets makes an enormous difference in bushels required to plant an acre and therefore in the cost of planting. Beaumont (*Mass. Sta. Bul.* 318) found that it would take, respectively, about 8, 25, and 95 bushels of sets of the sizes ⅜, ⅝, and ⅞ inch to plant an acre.

Sets are best stored at a temperature of 30° to 32° F. After storage at medium temperatures, 40° to 50° F., premature seeding becomes serious. High temperatures favor deterioration of sets.[11] See Chapter 7.

CULTURAL METHODS

Weed control. The principal job with onions between seeding and harvest is weed control. Choosing clean land, faithful attention to cultivation as needed during early growth, and hand weeding are the usual measures. Cultivation should be with

blades on wheel hoe or tractor rather than with teeth. Scuffle or shove-hoes are used on muck soils.

Chemical weed control is by means of calcium cyanamid before emergence of seedlings and potassium cyanate or chloro I.P.C. afterward. Directions from manufacturer or experiment stations must be followed with great care to insure a good kill with minimum injury to plants.

Irrigation. Hawthorn [6] recommends that irrigation be gauged by observations on rate of evaporation of water from an open surface. He suggests less frequent watering early in growth and more frequent applications as bulbs are developing. Over-irrigation is harmful, the effect becoming evident in poor color of leaves. Usually 5 to 8 applications of water are made in Texas, either by furrow or flooding. Fields are often laid out along the contours.

Curry (*N. Mex. Sta. Bul.* 281) over a period of 5 years found that frequent (weekly) irrigations give best yields with Early Grano onions; he used an average of 12 applications and a total of 25 acre-inches of water for the crop season

Onions on good deep muck seldom suffer seriously from drouth.

In irrigating onions, it should be remembered that the plant is characterized by a narrow and rather sparse root system. Irregular irrigation may increase the proportion of splits and doubles, and overwatering may favor thick necks. Definite rules for irrigation cannot be laid down, but balance among these various factors must be considered in deciding on practices.

DISEASES AND INSECTS

Diseases

Smut, caused by *Urocystis cepulae,* is responsible for heavier losses than any other onion disease, especially in the early stages of growth of seedlings. Sets or transplants are little damaged. The disease appears as dark streaks on the leaves, which later break open, releasing black powdery spores.

Seed is treated with tersan and a methocel sticker or, if infestation is not severe, with arasan. Another control in seedlings is by the use of formaldehyde solution, 1 gallon of formalin to 65 gallons of water. Formalin is a 40% solution of formaldehyde gas in water. The rate of application is varied somewhat

according to dryness of the soil. The solution is applied from a tank mounted on the seed drill, a tube being adjusted to deliver about 100 gallons per acre or a gallon per 300 feet of row. Recommendations of different states vary somewhat.

Neck-rot, caused by *Botrytis* spp., is primarily a storage disease but may affect growth of the plants. It causes rot in storage, and infected sets give poor come-up when planted. The infection usually takes place at curing time, through exposed moist tissue. Thick-necked bulbs are more susceptible than normal ones, and mechanical injury affords easy entrance for the fungus. Prompt, thorough curing of bulbs and storage at low temperature and humidity tend to check the trouble.

Downy mildew or blight, the causative agent of which is *Peronospora destructor,* attacks onions late in their growth, causing premature dying of the foliage and reduced yields. It is favored by a combination of high moisture, cool nights, and warm days. The organism winters over in stored sets, in diseased refuse, and especially in perennial onions. The importance of this last host has been demonstrated by Newhall,[9] and some communities have reduced losses greatly by cooperating in clearing the neighborhood of these winter onions. Newhall studied the flight of spores by exposing culture plates from an airplane. Spraying with carbamates (Dithane, Parzate, etc.) has proved practical; it has also reduced the amount of *blast,* a dying of the onion leaf tips.

Pink root, caused by *Phoma terrestris,* is serious in Texas and in lesser degree elsewhere. The fungus survives in the soil. Roots turn pinkish and die. Partial root replacement occurs, but plants do not thrive and yields are reduced. No treatment offers effective control. Special care is necessary to avoid planting seedbeds on infected land. Favorable conditions for rapid growth serve to reduce injury.

Insects

Onion maggot, *Hylemyia antiqua,* is the larva of a fly which winters in soil and refuse. Eggs are deposited in the soil around the plants or in leaf axils. On hatching, the larva or maggot feeds on the roots and developing bulb. Oil emulsion, diluted with Bordeaux, is sprayed on the plants when flies appear, wet-

ting both stem and soil. Two or three treatments are required a week or ten days apart.

Onion thrips, *Thrips tabaci,* is a minute insect about 1/25 inch long and very slender. Both nymphs and adults suck the juice of the plant, and the leaves assume a whitish chafed appearance. The thrips harbor in leaf axils and in angles of broken-over leaves; they are especially troublesome in dry weather. Control is with parathion or DDT. Effort is under way to breed strains of onions with round leaf bases which afford little shelter for the thrips.

MARKETING

Harvesting

Green bunch onions are harvested as soon as markets will take them, at a diameter of about 3/8 inch. They are peeled of outside skin (leaf bases) and bunched. Some are sold in bunches after they have begun to form bulbs, say, an inch in diameter, and until full size is reached.

Mature dry bulbs are harvested when the tops have died down. Many different procedures are followed. In the south, harvesting

Hart and Vick

FIG. 23.5. Topping, sorting, and packing mature dry onions.

may begin at a rather immature stage, and they are often pulled, topped, and shipped the same day. Many growers put the bulbs in bushel field crates as fast as they are pulled and topped, stacking them for curing, one crate wide and four high, and covering them for protection from rain. They are later stacked

with spacing for air circulation, in open sheds. Onion combines have been devised which lift and top the onions, which are then delivered to crates.

Starring (*Mont. Sta. Bul.* 305) found rolling the tops and cutting the roots ineffective as measures to further the dying down of tops and the maturing of bulbs. Rolling tended to reduce yields, as did severe root cutting.

Sorting

The standard for U. S. No. 1 onions calls for a minimum size of 1¼ inches. The sorting table has slats 1¼ or 1½ inches apart. Size may be further designated as 1½ inches minimum or as the percentage over 2 inches. Small onions are sold as culls or boilers. Thick-necked, diseased, damaged, and soft onions are sorted out as they pass over the sorting table.

Packages

Onions are usually sold in 50-pound burlap or paper mesh bags. A part of the crop is put up in 5- and 10-pound bags of paper mesh or kraft paper. Marketers frequently use printed bags. Some fancy Sweet Spanish onions are packed in 50-pound crates.

STORAGE

Onions are best stored at a temperature of 32° to 34° F. with low humidity (64%).[11] No attempt should be made to store diseased, poorly matured, thick-necked, or otherwise defective onions. Storage losses take the form of decay, sprouting, root development, and softening and shrinkage of tissue, the last caused primarily by evaporation and respiration. Onions are not as sensitive to freezing injury as some vegetables. If not handled while frozen and if not subjected to alternate freezing and thawing, injury may not be serious. This does not mean that freezing is good for onions.

Magruder[12] and associates have placed major varieties in five classes according to suitability for storage:

Very poor	Italian Red
Poor	Crystal Wax Yellow Bermuda Early Grano (Babosa)

Fair	**Sweet Spanish**
Good	**Early Yellow Globe** **Southport** **Ebenezer**
Very good	**Creole** **Australian Brown**

Common storage of onions in insulated buildings with ample ventilation is customary. Field crates are used, with spacing both ways for free air circulation. Onions may be held in open cribs until freezing weather. The freezing point of onions is about 29° or 30° F.

Cold storage is increasingly used for onions, and here humidity is controlled by means of the refrigeration equipment. The atmosphere of storage rooms may be kept dry by means of calcium chloride spread on open metal trays. This is a deliquescent or water-gathering chemical salt. The material may be used again after drying.

Cleaver (*Ind. Sta. Bul.* 393) has shown the influence of quality of onions upon keeping. He found, in a single year's trial, that U. S. No. 1 onions lost 7.2% in weight, and onions just short of U. S. No. 1 lost 11.2%. Over half the difference was traceable to decay.

Maleic hydrazide sprayed in fields before harvest will inhibit sprouting of onions in storage. If applied too early or too heavily, there may be trouble with softening of bulbs. Get advice, and follow directions.

CONCERNING THE ONION

Food use

The onion ranks about medium in calorie value, is low in protein and ash, and is not particularly high in vitamins. Its major value lies in its flavor. It is an excellent vegetable when boiled and served either buttered or creamed. In this form it lacks the strong and persistent flavor that gives offense to some. Onions are widely used to add flavor to stews, gravies, stuffings, soups, and fried meats, and also raw in sandwiches. Green onions are served as a relish or appetizer. Onions are dehydrated for general use or powdered for flavoring purposes. A few are canned or pickled.

Many years ago Lemmler in Germany traced the pungency of the flavor of onions to a sulfur-bearing compound present in very small amounts (about 0.005%) in the volatile oil of the plant juice. Platenius[18] has developed a relatively simple method for determining the content of volatile sulfur which gives a good measure of the pungency or strength of onions. The compound is allyl propyl disulfide, sometimes called allyl sulfide:

$$\begin{array}{l} C_3H_7\text{—}S \\ \qquad\quad | \\ C_3H_5\text{—}S \end{array}$$

Some varieties show more than twice as much volatile sulfur as others.

Botany

The genus *Allium* includes the common bulbing onion and several other species as given under varieties. This genus has been divorced from the family Liliaceae, where it lived happily (as far as vegetable growers are concerned) for decades, and is now attached to the family Amaryllidaceae, which includes the narcissus and amaryllis.

The bulb consists of the bases of leaves, arranged concentrically, each leaf emerging through a close-fitting opening in the sheath of the next older leaf.

The stem remains a low disc or dome until seed-stalk development begins; then it elongates rapidly and becomes tubular.

Leaves, except in the leek, are hollow, cylindrical, and tapering. There may be more than one growing point on the stem, and then splits or doubles are likely to result.

The inflorescence, a globular umbel, is enclosed by a thin membranous spathe. The head, consisting of many white flowers, is a thing of beauty, singly or in a field. Pollination is by insects, and pollen is shed before the stigma becomes receptive, favoring cross pollination. The ovary consists of three locules or cells, each containing two seeds. black and flattened on adjacent sides.

Breeding

In the earlier days reliance in breeding rested upon simple selection. More recently pure-line breeding, selfing, and con-

trolled crossing have been practiced by methods largely developed by H. A. Jones [14] and his associates. Bagging, caging, and use of artificially reared flies were among the usual tools. Development of male-sterile lines has greatly facilitated the work. Inbreeding results in loss of vigor which is restored on crossing—a matter of hybrid vigor or heterosis (page 103). Notable improvement in many varieties has been achieved by these methods.

The onion has been the subject of a series of studies that illustrate beautifully the interrelations of biology, chemistry, and genetics. Walker and associates studied smudge, a fungus disease of onions, finding it prevalent in white but not in red or yellow varieties. Link and others learned that protocatechuic acid is toxic to the fungus and that it is present in pigmented varieties. Rieman [15] then established the relationships of genetic factors governing the inheritance of the capacity to produce the pigments. Thus disease resistance in this case is governed by the inheritance of factors affecting the development of a pigment which carries a chemical compound toxic to the causal fungus.

Seed production

Seed is produced in the north by storing bulbs and setting them out in the spring. In California bulbs are harvested, sorted, and sacked and may be set out during fall or winter months. Seed is recovered by threshing or flailing and is washed in order to float away light seed.

Viability of onion seed declines rather rapidly, but Beattie and Boswell [16b] have shown that if seed is dried to 6% moisture content and held at 20° to 40° F., it will keep well for at least seven years. A temperature of 40° F. seems better up to four years, the lower temperature for longer storage.

Importance

The onion ranks about fifth among vegetable crops in value, and is about tenth in acreage involved.

Texas has by far the largest onion acreage, but New York, through high yield, gets nearly as much money for its crop even though unit price is lower. Texas enjoys the high seasonal price of spring markets, but yields are low. Other leading states in order of acreage are New York, California, and Michigan.

Onion production areas are usually concentrated, as in the Laredo section of Texas, and Orange County, New York.

Yields, costs, and returns

The average yield of onions over the 10-year period 1941–1950 was 300 bags (50 pounds) per acre; but the average for 1950–1951 was 360 bags. The average yield in Texas is under 100 bags per acre; in California, Massachusetts, and New York it is usually above 400 bags, and Idaho's 10-year average is over 600 bags. Yields of 1,200 bags are occasionally reached.

History

The onion was known in earliest times; it is pictured on Egyptian monuments and is mentioned in the Bible. One legend relates that, when Satan departed from Eden, the onion grew in the prints of his right foot, garlic in the left. It is mentioned in literature from Hippocrates, the Greek physician (430 B.C.), down to the present time. Chaucer, 1340, said, 'Wel loved he garleek, onyons and eke leekes."

Primitive wild forms of the onion itself are not known. It is not clear whether any form of onion was native in the Americas, but Indians used it from early times. Danvers and Wethersfield are among our oldest varieties.

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24

Cabbage and Related Crops

> They are beautiful. Like jade and Burgundy—like chrysoprase and porphyry. All those fields of cabbages and the corn and the beet-tops together look like Persian patches.
> —EDNA FERBER, *So Big*, p. 25.

Cabbage and its cousins are widely used as vegetables, and they are easy to grow. Their family, Cruciferae, stands out distinctly from others but offers difficult botanical problems within itself. The various kinds of vegetables are hard to separate botanically, but they differ conspicuously in their habits of growth and in the parts of them that we use.

The parts we use. The cabbage head itself is an enlarged and exaggerated terminal bud. Cauliflower and broccoli are flowering heads, Brussels sprouts are axillary leafy buds, kale and collards are bunches of leaves, turnips and rutabagas are enlarged roots, and kohlrabi is an enlarged stem. The radish also belongs to this family but is of a distinct and easily separated genus.

One common character of the vegetables of this family is the pungent flavor of their juice, mild in cabbage but very marked in the condiments mustard and horse radish. This flavor is traceable to an organic compound, a glucoside, which carries sulfur and is called sinigrin.

The flowers are four-petaled, giving the name crucifer or crossbearer. The plant is normally a biennial, producing seed the second year.

Cabbage is discussed as the typical crop of the family, leaving other crops to be treated briefly later.

ADAPTATION

Cabbage grows easily under a wide variety of conditions, during the northern summer and the far-southern winter, or as a spring or fall crop in regions between.

Year-round crop. Cabbage is on the market every month of the year, and prices are likely to be disastrously low at any place

FIG. 24.1. Broccoli, Italian Green Sprouting.

and any time except perhaps in June and early July in the north. Judicious planning of maturities is necessary to increase the chances of obtaining good prices and to avoid annually recurring glutted markets. In 1950 cabbage was plowed under in Texas, and much was sold at $6 or $8 a ton, a ruinous price for southern conditions. In that year the average price of the Texas winter crop was $12.80 a ton; the next year, $68. Nevertheless, in 1950 it sold for 4 cents a pound retail in New York. At the beginning of the northern marketing season, growers may receive 3 and 4 cents a pound and occasionally more. But many a car has been loaded with cabbage in Wisconsin and New York at $8 a ton, balancing years when it may bring $40 to $50, occasionally more, at harvest time.

Fig 242 Catskill brussels sprouts.

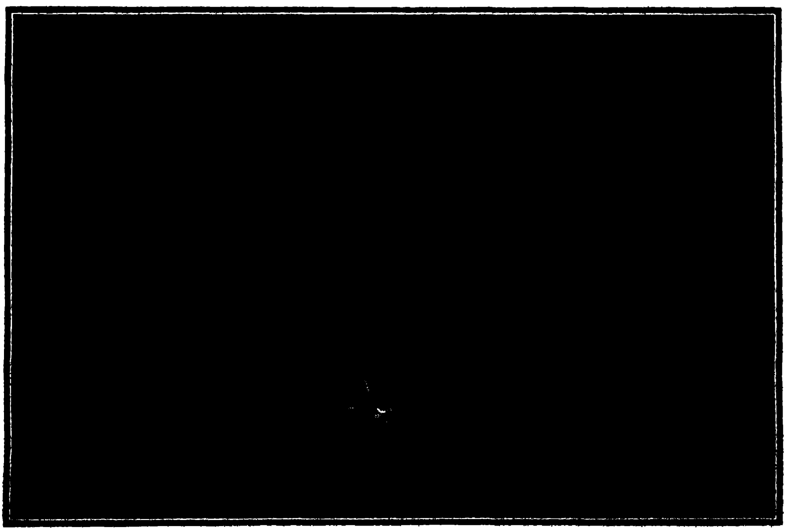


Fig 243. Kale.

Frost resistance. Well-hardened plants withstand frost down to 20° or even 15° F. In the mid-south it is common practice to set plants in the fall, in order to make some growth then, but to develop for marketing in the early spring. Certain varieties are seriously subject to premature seeding under these conditions. In the north, plants may be set as soon as the ground can be made ready. Late cabbage withstands some freezing in the fall, although alternate freezing and thawing may damage the heads.

FIG. 244. Chinese cabbage of several types.

Rainfall. Misner (*N. Y., Cornell, Sta. Bul.* 443) studying late cabbage production and marketing, found a close statistical correlation between the rainfall during July, August, and September of any year and the size and price of the crop of late cabbage in New York. Rainfall influences price more than does acreage planted, which normally does not fluctuate widely.

Soils for cabbage range from light sandy loams to the heavy clay loams for the late fall crop in the north. Cabbage is moderately tolerant of acidity, *p*H as low as 5.5, but, where clubroot is prevalent, reaction should be brought to about *p*H 7.2, using hydrated lime. Cabbage responds to liberal moisture supply, fertility, and organic matter, and it requires good drainage. It is generally said to be a heavy feeder, perhaps because of an insistent requirement for adequate nitrogen supply.

SOIL MANAGEMENT

Long rotation is desirable for cabbage if the clubroot disease is prevalent. Some general farmers plant cabbage on part of a

3- or 4-year rotation area, thus bringing this crop to the same land not oftener than every 6 or 8 years. A well-maintained rotation system, including legumes and sod, furnishes good conditions for late cabbage.

Fertility. Cabbage responds to liberal fertilization whether in the form of stable manure or of a combination of green manure crops and commercial fertilizer. Maintenance of organic matter in the soil is important for cabbage. For the early crop on sandy soils 75 to 125 pounds each of nitrogen, phosphoric acid, and potash will serve until local advice and experience afford a better plan.

For late cabbage in the north, manure plus 100 to 150 pounds per acre of phosphoric acid is good, fertilizing more liberally if the yield and the price of produce justify it. Late cabbage is often very cheap in the north, $8.00 a ton at car door and even less. Careful calculation is therefore necessary to devise a program that will yield heavily of good cabbage at the minimum cost per ton. At the same time, increasing yield is an effective means of lowering the cost per ton. Thus $15 per acre invested in 500 pounds of extra fertilizer is profitable, even at very low cabbage prices, if it will increase the yield by 3 tons or more. On the other hand if something other than fertilizer is the limiting factor, it will not pay.

Placement of fertilizer in bands beside the row is good practice on sandy soils or where general fertility is not high; side dressing with nitrogen also may be desirable.

VARIETIES

A good cabbage variety is selected with the following characters in mind:

1. Appropriate earliness or lateness.
2. Vigorous plant growth and heavy yield.
3. Solid round head of good size, oversize being avoided by close planting.
4. Leaves closely packed within the head, core short and small; not disposed to burst quickly.
5. Flavor mild and sweet; texture crisp and tender.
6. Resistance to fusarium or yellows disease.

Cabbage varieties shade from one to another, with many strains, resulting in considerable confusion. When ordering Copenhagen, you may get one thing this year and another thing next, unless you deal with good seed houses, tell exactly what you want, and keep track of lot numbers.

See Boswell et al. (ref. 12, Chapter 8) and Morrison et al.[2] for descriptions of varieties.

Jersey Wakefield is our earliest variety. The head is small, pointed or ovate, solid at the base, inclined to be soft at the top, tender, crisp, and of high table quality. It is grown in the south because it does not bolt to seed readily, but round varieties are replacing it as strains are bred to meet the requirements. **Charleston Wakefield** is later, larger, and broader at the base. **Jersey Queen** is a fusarium-resistant strain.

Golden Acre, Copenhagen, and **Glory** are similar in type, making a series in size of head and earliness of maturity Golden Acre is nearly as early

FIG. 24 5. Golden Acre cabbage. Leading early variety.

as Jersey Wakefield, and is important for early market. Glory is two or three weeks later, an excellent midseason and kraut variety. Various strains of Copenhagen range from Golden Acre to Glory, inclusive of both. All three are round, with somewhat wavy leaf margins. Glory is very heavy yielding. Yellows-resistant strains are **Racine Market, Detroit, Marion Market, and Globe. Louisiana Copenhagen** has been bred by J. C. Miller for compactness, short core, and resistance to cold and bolting.

Bonanza is a round-headed, midseason variety, whose heads are very hard when small and stand long without bursting.

All Seasons and **Succession** are vigorous, heavy-yielding, flat-headed, midseason varieties, used to some extent for kraut. Newer strains are deeper in shape than old ones. **Wisconsin All Season** is fusarium resistant.

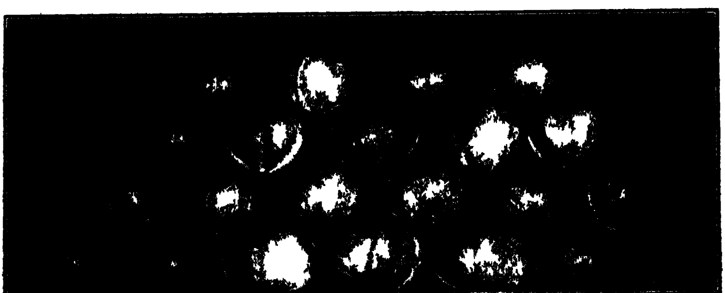
Early Round Dutch has maintained a place in the south because it winters well and yields heavily.

Danish Ballhead, or simply **Danish,** is the leading late variety for fall harvest in the north for both market and storage. It grows vigorously

Ferry Morse Seed Company

FIG. 24.6 Chieftain Savoy.

and is erect in habit; its outer leaves are numerous and slightly frilled. The head is nearly round, slightly tapering at the base, slightly flattened on top. Many strains of Danish have been bred, varying in size, yield, shape, adaptation, and performance; many are more flattened in shape than they should be **Penn State Ballhead** and a number of other strains



Jos Harris Company

FIG. 24.7 Danish Ballhead. The best type is nearly round and slightly tapering at the base—lower right head. Some of the others are too flat for good Danish.

of merit are similar. **Oakview Ballhead** is of medium size, round, solid, and very well bred. **Wisconsin Danish** is fusarium resistant, as is **Wisconsin Hollander**, which is large and coarse in growth.

Red Rock and **Red Danish** are similar in type to Danish Ballhead but carry purple pigment, an anthocyanin. This pigment is distinct from the sun-red which appears on a good many white varieties, notably Danish, visible where leaves are exposed to the sun but not where they are covered.

Savoy varieties and strains, early and late, of various sizes and shapes, are marked by leaves which are finely crumpled in surface, sometimes, but not correctly, called blistered. Cooking odors of Savoy varieties are less conspicuous than those of other cabbages, and **Cornell Early Savoy** of C. H. Myers received publicity as "odorless cabbage" although its originator claimed only that it is less potent than others.

PLANT GROWING

Cabbage plants in the south are usually started in outdoor seedbeds, as are plants for the northern late crop. Plants for the northern early crop are started under glass. See Chapter 9.

Open seedbeds. Outdoor seedbeds should be in soil that is of good physical characteristics, friable, and not subject to crusting which may interfere with come-up. It should be free of disease, especially of clubroot and of nematodes. Could you imagine a better way to inoculate a field thoroughly and systematically than to set plants from a seedbed infested with clubroot? If clean ground cannot be found, seedbeds may be sterilized with formaldehyde, chloropicrin, steam, or hot water, but these treatments are rather costly and troublesome.

Fertility in the seedbed should be ample but not excessive, in the interest of plants that are well hardened and not overgrown.

Accessibility of water is important especially if plants are wanted at a definite time.

Sowing seed. Most seedbeds are sown much too thickly, resulting in crowded, soft, weak, spindly plants. At setting time the stem should be ⅛ to ¼ inch in diameter, never larger than an ordinary pencil. Height may well be 5 to 8 inches. If too old or too big, they are more likely to bolt or go to seed prematurely, especially in the south, after they have been exposed to cold weather. Rows may be 8 to 16 inches apart as is convenient, sowed not over 20 or 25 seeds per foot, assuming 90% germination. This should give easily 15 to 20 plants per foot. That would mean about 600 feet of row for 10,000 plants, enough

for an acre. Such planting economizes in seed, which runs 8,000 to 10,000 per ounce. Many growers figure on sowing ¼ pound of seed for each acre to be set, and some use ½ pound. This liberal allowance is all right if seed is not sowed too thickly, for it provides against unfavorable conditions for plant production and also affords extra plants to sell.

The seedbed should be prepared very carefully, so that come-up will be full and even. This requires even depth and coverage.

In the north, when days are long, plants can be grown very nicely in 6 weeks, say April 15 to June 1. In the south, experience will have to teach, but the required time in the late summer or fall may be longer, as days are short and weather may be cool.

Northern plants under glass. Cabbage plants are started under glass, following the principles of Chapter 9. Seven to eight weeks should be allowed, and plans should be made for thorough hardening. Cabbage renews growth speedily after checking, although overhardening is not desirable. Plants are usually transplanted just once before going to the field. They are grown under cool conditions, 50° to 65° F. Premature seeding is favored by low temperature and oversized plants.[4] See also page 106.

Cabbage plants are successfully shipped, and many millions are grown in the south for setting in the north. See page 150.

PLANTING

Cabbage is almost always transplanted to the field, although sowing in a permanent place and thinning are practiced to some extent both north and south. In general it is easier to care for little plants and to keep the field free of weeds under the transplanting plan.

Land should be carefully prepared so that there can be close and uniform contact between plants and soil.

Planting times. Early cabbage in the north is set as soon as ground can be prepared, but good, well-hardened plants are necessary for this. Late cabbage, from Massachusetts to Minnesota, should be set by June 15. Late cabbage will make a crop if it gets good growing conditions whether early or late, but timely setting reduces the risk of lowered yield on account of drouth or exceptionally cold and wet weather. Danish cabbage

does not burst seriously, and, even though it matures somewhat earlier than desired, it will stand in the field without harm, although storage cabbage is considered to keep better if a trifle immature.

Planting times in the south must be gauged according to local climate and best seasons for marketing. Much cabbage from Maryland to Georgia is set in the fall to grow and mature in early spring. Growth is much slower in the southern winter than in northern summer.

Level culture is usual for cabbage, but when plants are set in the fall it is well to make a ridge, east and west, and to plant on the south side, taking advantage of both sunshine and shelter from cold winds. Ridges or raised beds are necessary for furrow irrigation.

Spacing of cabbage plants is governed largely by the size of the heads that are wanted. Overlarge heads are at a disadvantage in marketing; 3 to 4 pounds is a good size. Large size is not objectionable for kraut. Heads of small to medium size can be obtained by planting heavy-yielding varieties and fertilizing for a big crop and then planting closely. This commonly means 15 to 18 inches in rows 30 to 36 inches apart for the late crop and 8 to 12 inches for early. Where weeds are bad, check-row planting may be desirable.

Transplanting machines requiring a crew of 4 to 8 workers are often used for cabbage; for large operations they are probably desirable. On a smaller scale much time can be lost. See page 211.

Pruning of plants should be practiced only under exceptional conditions. It is far better to sow seed at the right time, to keep plants within bounds for size, to keep them on the dry side for a good root system, and then to set them intact. In pulling plants, care should be taken to damage the root system as little as possible. With fair treatment, cabbage is transplanted readily and recovers speedily.

CULTURE

Cultivation and weeding of cabbage are managed as with other crops. Chemical control is not yet available.

Irrigation in the west is usually by furrow methods. Sprinkler systems are used in other areas, though chiefly for early crops.

Late northern cabbage is seldom irrigated, although adequate water supply contributes importantly to both yield and quality.

Cabbage, especially of early and midseason round varieties, is subject to bursting when dry weather is followed by rains or when irrigation applications cause uneven soil moisture.

DISEASES AND INSECTS

Diseases

Clubroot is caused by *Plasmodiophora brassicae*, which was formerly classified as a myxomycete or slime mold but is now recognized as a rather primitive or rudimentary fungus. The organism survives in the soil, invades the roots, interferes with water passage, and so retards growth and causes wilting. It also favors decay of heads after harvest. The roots become swollen into enlarged knobs or galls. Both clubroot and fusarium may occasion wilting of leaves, with recovery overnight during the early stages. Clubroot is freely carried by surface drainage.

Control is by long-time rotation and by the application of lime to bring the soil *p*H to about *p*H 7.2 using hydrated lime. Some success has been achieved by use of calomel in suspension (7½ pounds per acre) or bichloride of mercury (1 part to 2,000) in the transplanting water. These must not be used with starter solution.

Fusarium or **Yellows,** caused by *Fusarium conglutinans*, like other diseases of this genus infects plants from the soil and clogs the conducting tissues, dwarfing and yellowing the leaves, which later may drop. Fusarium is recognized by darkening of vascular bundles in cross sections of leaf petioles. Resistant strains and varieties offer the only means of control. L. R. Jones, J. C. Walker, and associates [7] in Wisconsin have led in breeding many such strains.

Black rot, a bacterial disease caused by *Xanthomonas campestris*, harbors on seed or in remains of cruciferous plants in the field. It causes yellowing of leaves, blackening of veins, dwarfing, and, later, rotting of tissues. Control is through the use of disease-free soil for the seedbed, rotation, and clean seed, that is, seed from disease-free crops in favorable production regions or else seed treatment. As the inoculum is carried on the seed

surface, bichloride of mercury (1 to 1,000) is effective, soaking seed for 20 to 30 minutes and rinsing and drying. Hot-water treatment as used for black leg is also effective but is not required for black rot alone.

Black leg, caused by the fungus *Phoma lingam,* appears as dark sunken areas on the stem, followed by decay of stem and roots, and later wilting and death. Crop rotation and seed from disease-free regions are helpful. The fungus is within the seeds so that exterior treatments are ineffective. Many seedsmen and some growers treat seeds with hot water at 122° F. for 25 minutes. This is intended to be drastic enough to kill the fungus but not the embryo. Hence it must be applied accurately. If seed is weak in germination, some harm may be done. Some seedsmen supply treated seed.

Insects

Cabbage worm, *Pieris rapae* (*Ascia rapae*), is the common green eater of cabbage leaves, the larva of the dainty white butterfly that hovers about the fields. It attacks all crucifers practically everywhere. Rotenone or DDT sprays or dusts are effective. Spray should include good sticker and spreader on account of the waxy bloom of the leaves. **Diamond-back moth,** *Plutella maculipennis,* and the **looper,** *Autographa brassicae,* are controlled in the same way.

Cabbage aphid, *Aphis brassicae,* often appears first on a few plants here and there, curling the leaves and stunting the growth. Hence careful watch followed by spot dusting is practical. Parathion and nicotine are effective. After leaves have curled and aphids have attacked the center of the plant, control is not practical.

Cabbage maggot, *Hylemyia brassicae,* attacks seedbeds and early field plantings. A small fly emerges about the time plums and cherries bloom and lays tiny but visible eggs at the point where stem and soil join. The larvae hatch and burrow into the stem, causing dwarfing, yellowing, wilting, and sometimes death of plants. For control, use bichloride of mercury, $HgCl_2$ (corrosive sublimate), or Calomel, HgCl. Chlordane as dust or in the transplanting solution is less expensive and equally effective.

Cutworms, various species of the order Noctuidae, often cut cabbage plants soon after setting. Avoid sod land, wrap stem with paper, or use poison bait made as follows:

	For 10 Acres	*For 150 Plants*
Bran	100 lb.	1½ lb.
Sodium arsenite	2 qt.	1/16 pt. or 30 cc.
Black molasses	2 gal.	¼ pt.
Water, about	7-8 gal.	1 pt.

Spread the bait in the form of a mash at the rate of about 10 pounds per acre.

Harlequin bug, *Murgantia histrionica,* is a serious cabbage enemy in the south. It is a true stink bug with a gay red and black coat. It is hard to control. The eggs look like little white barrels with black hoops and a spot at the bung. DDT affords effective control but should not be used as the crop nears maturity. Keeping down weeds, especially the crucifers, use of trap crops, and hand picking when the bugs first appear are all useful means of control.

HARVESTING AND MARKETING

Harvesting. Early cabbage is cut and sold as soon as the price and size of heads warrant, often before heads are very solid, and they are shipped with several wrapper leaves. As the season advances, heads are allowed to attain full weight and maturity. E. N. Reed has devised a good knife, Fig. 24.8. The heads are cut very rapidly with the knife, leaving the cabbages with three or four wrapper leaves. Butcher knives are common but less efficient, and they are hard on the hands. A blade fastened to a long handle makes stooping unnecessary; a hoe straightened at the shank serves well. The heads are rolled into windrows of 4 rows each. A truck goes through, and heads are tossed in, care being taken to avoid bruising by rough handling. An inconspicuous bruise often leads to decay and heavy trimming. Removal of only four or five leaves may result in 10% loss of weight.

Kraut cabbage, after being cut, is usually handled with a pitchfork. Late and kraut cabbage are usually cut over but once; early cabbage, two or three times.

Packages. Cabbage for immediate sale is generally packed in the field, although shed packing is practiced in some southern

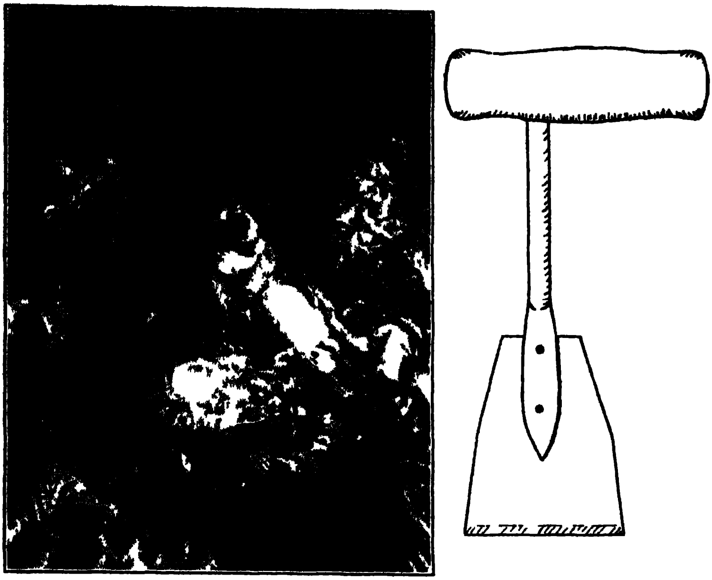


FIG 248 A handy knife which saves blisters and is easily managed to cut to just the right trim

truck-crop areas The usual package is the mesh bag, but Los Angeles lettuce crates, half lettuce crates, and bushel or bushel-and-a-half hamper baskets are also used. Late cabbage in the

FIG 249 Guy Stutzman of Pennsylvania has brought the harvesting and handling of 90 acres of Danish cabbage to high efficiency. Note tractor and trailer for pickup

north is often moved in burlap bags holding about 50 pounds. The bag is not a good package because the heads are scuffed and scarred every time it is moved.

FIG 24 10 Texas cabbage moves in both bags and crates These bags are of open-mesh burlap

STORAGE

Cabbage storage in the north is not as important as formerly since southern areas are able to ship a fresh product practically all winter. Some consumers prefer old white cabbage; some, young green heads. In fact, trucks have been known to bring green cabbage north and return southward with a load of white cabbage from storage.

Cabbage in storage requires a temperature just above freezing and high humidity. Free moisture on the heads, occasioned by fluctuating temperature and the consequent condensation, is harmful and encourages the development of disease.

A well-insulated and frost-proof building or basement affords good storage conditions for cabbage. Ventilation openings in the roof may be desirable for temperature control, but often the doors are sufficient. Much changing of air results in evaporation and increased shrinkage.

If heat is necessary, simple stoves or even adapted oil drums may be used with coke or charcoal and without a chimney. The fumes seem to do no harm.

Outdoor storage. Cabbage may be buried in pits, roots and leaves on, or set into soil, and covered with straw and soil. Quantities of cabbage have been stored in the north by laying the cut heads on sod and covering with a foot or so of leaves or straw. The heads usually freeze and keep fairly well, provided there is little alternation of freezing and thawing. Such cabbage must be taken to a warmer place to thaw before shipping.

For home use, cabbage may be stored under cool, moist conditions along with Irish potatoes, beets, carrots, and the like.

Quality for storage. Cabbage for storage should be perfectly sound and not overmature; the heads should have, for protection, three or four wrapper leaves, to be trimmed off when packed out for market. The usual variety is Danish Ballhead, although a little red cabbage is stored.

Storing too early, while weather is warm, results in rapid deterioration by respiration, evaporation, and decay. Delaying storage too long may result in loss from freezing in the field and in the inconvenience and poorer condition resulting from wet weather and muddy fields.

CONCERNING CABBAGE

Food use

Cabbage carries 92% water and is low in calorie value, though higher than lettuce and cucumbers. Minerals (ash) in cabbage stand higher than in tomatoes but about half as high as in spinach. Cabbage ranks low in carotinoids or vitamin A, medium in B_1, thiamin, and G, riboflavin, and high in C, ascorbic acid. Young green heads are higher in carotinoids than old white cabbage.

Cole slaw is a common and appetizing way of serving raw cabbage. Cabbage may be boiled alone, the cooking time being short, about 12 or 15 minutes. It is also boiled in combination with other vegetables and meat and should be put in the pot when the meat is nearly done. The traditional New England boiled dinner is a beloved concoction of this sort. Corned beef and cabbage is a homely but popular dish.

Sauerkraut is cabbage fermented by lactic acid bacteria, *Bacillus lactis acidi,* in the presence of salt. These bacteria are the organisms of sour milk. Cabbage is trimmed, sliced fine,

and packed into great vats, with 2 to 3% salt which withdraws moisture from the cabbage. Inoculation is natural, artificial methods having shown no advantage. Vats carry from 30 to 70 tons, and wooden covers are weighted down to keep the cabbage immersed. The fermentation may be adequate in three or four weeks but may continue longer. The lactic acid content, resulting from fermentation of sugars, reaches a maximum of about 2%; when canned, 1½%. The kraut is usually canned. Home-made sauerkraut is good and is easily made; it keeps well in a container as small as a gallon crock. See home economics publications on food preservation for directions.

Botany

The cabbage family is clearly separated from other families, but botânic separations within the family are arbitrary and difficult.[9] The family includes sweet alyssum, candytuft, stock, and many wild mustards and cresses. Most of the vegetables of the family belong to the genus *Brassica;* five are varieties of a single species. Name derivations are given to aid the memory.

B. oleracea var. *capitata* (L. *Brassica,* classical name; *olus, oleris,* vegetable; *capitata,* headed), cabbage.
B. oleracea var. *acephala* (Gr. without head), kale.
B. oleracea var. *gemmifera* (L. bud-bearing), Brussels sprouts.
B. oleracea var. *botrytis* (Gr. budding), cauliflower.
B. oleracea var. *italica* (Italian), sprouting broccoli.
B. caulorapa (L. stem-turnip), kohlrabi.
B. napobrassica (L. *napo,* turnip), rutabaga.
B. rapa (L. turnip), turnip.
B. hirta (*B. nigra*), mustard.
B. pekinensis, B. chinensis (of Peking, China; *ensis* = inhabiting), Chinese cabbage.
Nasturtium officinale (L. *nasturtium,* nose-twister), water cress.
Armoracia apathifolia, horse-radish.
Raphanus sativus (classical name; *sativus,* food), radish.

The stem is fleshy and remains short in the cabbage until the second year when it elongates prior to blossoming.

Leaves are broad, round, heavily veined, thick, and rather fleshy. Some are almost smooth, some clearly crumpled or savoyed. A marked waxy bloom is present in most, turnip and

radish being exceptions. Thus leaves are difficult to wet with spray and require use of spreader and sticker.

Flowers of the family are in racemes and are numerous and mostly bright yellow. Pollination is by insects, and crossing is usual. Wide separation of fields is necessary for isolation.

The seed is globular, nearly smooth, and about $\frac{1}{16}$ inch in diameter. Germination is prompt and strong, considering the size of the seed.

Breeding

Crossing and selfing are sometimes difficult, owing to sterility problems. Often, as shown by Pearson,[10] this is due to pollen and pistil maturing at different times. Pollination before flowers open, accomplished by pulling away the petals, frequently solves the problem.

Much improvement of cabbage has been achieved under modern breeding methods, notably by Jones and Walker[7] of Wisconsin, C. E. Myers of the Pennsylvania State College, C. H. Myers of Cornell University, and others, including both station and commercial workers.

Seed production

Seed has been extensively imported from Denmark and Holland, but a well-established industry in the Puget Sound region of Washington has produced much of our seed for years. Seed is sowed in early summer. Plants are set in late summer or early fall; they remain in the field over the winter and go to seed in the spring. Stalks are harvested by hand and handled on canvas to avoid loss of seed, which is flailed or threshed out and milled. In climates of more rigorous winter, it is necessary to lift plants and store them, either by trenching or pitting or in common storage. Miller[4] has shown that seed may be harvested in the same season from spring-sown plants if they are subjected to low temperature, about 40° F., for two months.

Importance

Cabbage is a cheap food much used by laboring people, especially those of European parentage. Normally about 130,000 acres is grown for market. Kraut making calls for about 18,000 acres. New York is the leading state, with about 22,000 acres;

Texas follows with 18,000 acres, for winter and spring market. Cabbage in the United States is normally about a $50,000,000 crop, farm value.

Yields, costs, and returns

The average market yield is about 8 tons and, for kraut, about 11 tons per acre. Good farmers frequently obtain 15 to 20 tons of late cabbage per acre, and Reed Brothers in New York did not miss a 20-ton yield over a period of 30 years, a result of good farming and good seed of their own breeding. Mr. Reed reported a half acre of Glory yielding at the rate of 43 tons per acre. Early cabbage does not yield so heavily as late, 10 tons being considered very good. The average for Texas is only about 4½ tons. When a great quantity was sold in Texas at $6 a ton in the spring of 1950, someone was losing money.

History

Wild cabbage, edible and hardy, grows on the chalky Dover cliffs of England and in many other European coastal regions as well. There is also a wild form on the coasts of the Spanish peninsula. From these have been developed our many diverse forms of *Brassica* crops, from rutabaga to cauliflower. The Greeks knew and prized some cabbagelike plant which legend said sprung from the sweat of Jupiter when he strove to reconcile two conflicting oracles. Cabbage has been an important vegetable in many countries from ancient times. The Chinese are more familiar with the Chinese cabbage and the mustards than with our forms. It is possible that the hard-heading forms trace from northern Europe and from times since Charlemagne.

CAULIFLOWER

Cauliflower thrives only under cool and rather humid seasonal conditions. The maritime climates of Long Island and the Pacific coast, and also cool mountain climates with foggy nights as found in the Catskills, western Maryland, and Colorado, are good. The shores of the Great Lakes are reasonably favorable.

Soil management is handled about as for cabbage, but boron deficiency is a common trouble as shown by Dearborn.[12]

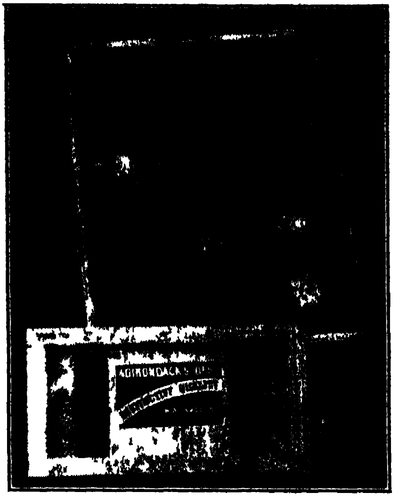


FIG 24 11 Cauliflower in the pony crate This is the usual western package, not yet common in the east

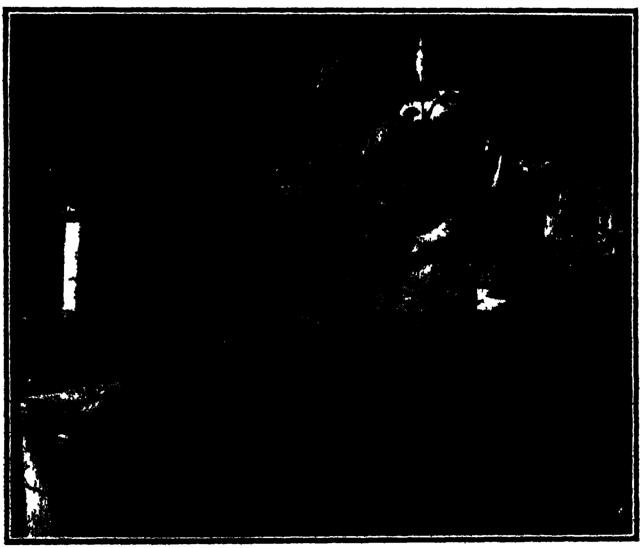


FIG 24 12. Packing cauliflower in western Maryland.

Varieties in the east are mostly of the Snowball group; various special strains requiring a much longer period to mature are used in California.

Blanching. To protect heads from light and to insure a beautiful white curd, leaves are tied over as soon as heads are an inch or two in diameter. String or rubber bands of different kinds or colors are used to distinguish those tied up at different times. Heads mature quickly and soon break into a "ricy" and uneven surface. Late fall cauliflower develops more slowly

SPROUTING BROCCOLI

Sprouting broccoli is now among the first 15 vegetables in acreage and value, production in 1952 showing a farm value of nearly $18 million. It has become an important crop for freezing, both home and commercial. It is one of the most rewarding crops for the home garden, being highly nutritious and delicious.

Broccoli is grown by much the same methods as cabbage, being more adaptable and easier to grow than cauliflower, and is successful under a wider range of conditions. In hardiness it is intermediate between cabbage and cauliflower.

The leading variety is **Italian Green Sprouting** or **Calabrese,** but there are many strains varying in maturity, uniformity of heading, and balance between center and side shoots. **DeCicco** is an excellent early variety. **Waltham 11** and **29** are well bred for spring and fall, respectively.

Plants may be started as for cabbage, but direct field seeding with subsequent thinning is common. Rows are 30 to 42 inches apart, and plants 15 to 30 inches in the row, according to growth habit of the variety.

Cultivation, weed, insect, and disease control are managed about as for cabbage.

The center heads of broccoli are cut when they have reached full size but before the buds break out of the compact mass in which they have developed. Side shoots come on for a long time and are used for both market and freezing.

Heads for fresh market are tied in bunches of 1 to 2 pounds and shipped, butts down, in flat crates.

BRUSSELS SPROUTS

Brussels sprouts, like cauliflower, thrive in a cool, humid climate. The principal center of production is in the Monterey Bay section of California, the "fog belt," but Long Island also grows the crop. Success depends upon use of good strains of seed and careful harvesting and marketing. **Catskill** is a good variety, with a short, compact cone.

KALE AND COLLARDS

Kale and collards are highly nutritious vegetables. Kale is grown as a winter crop in the Norfolk area for shipment and to some extent elsewhere. It deserves wider use as greens. In the home garden, it stands outdoors well into the winter. It should be planted in late summer so that plants are not large and overgrown, since the heart cluster of leaves is more tender and palatable than the coarse outer leaves. Collards are widely grown for home use in the south, and they deserve wider planting in the north.

TURNIPS AND RUTABAGAS

Statistical information on turnips and rutabagas is lacking. Turnip is *Brassica rapa;* rutabaga is *B. napobrassica.* On wholesale markets rutabagas are sometimes erroneously called turnips. The leaf of the former is thin and hairy; of the latter, thick, smooth, and waxy. Culture is about the same as for other root crops.

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25

Celery

Celeri has been found a very useful ingredient in the soup for seamen because of its antiscorbutic quality.—HENRY PHILLIPS, *History of Cultivated Vegetables*, London, 1827.

Celery is principally used as a pre-dinner appetizer, in salads, and as a flavoring in soups and dressings. It is an excellent vegetable either stewed or creamed.

Development of high-quality green varieties has resulted in diminished waste through fuller use of outside leaf stalks, besides providing celery that is good to eat.

Celery production has approximately doubled since 1935, although acreage has remained about the same. It is better than a $50 million crop.

TO GROW OR NOT TO GROW CELERY

Celery is a cool-season crop, grown in some parts of California during most of the year, produced in Florida in the winter and early spring. The main production in summer and early fall is on the mucklands from New York to Minnesota, where the summer is relatively cool. It is more tolerant of heat than lettuce, less tolerant than onions.

Soil. Celery is at its best on the muck soils, whether in Florida, in the California delta, or in the northeast. These soils usually furnish adequate moisture, a major requirement of celery. Excellent celery is grown on mineral soils that are well irrigated. Some users hold that the quality is better on such lands, but the farmers on muckland have been able to do the job at lower cost.

In Florida the Sanford celery area is a fine sandy soil, drained and subirrigated with tile; the Sarasota area is a sandy muck, and the Everglades is muck. California celery is grown on

alluvial and mucky alluvial soil in the delta region and on sandy soils in the south. Most of the crop in northern states, coast to coast, is on muck.

Celery requires well-drained soil, but it also needs a constant and liberal supply of water for the rapid growth that is necessary for succulence and tenderness. Celery has a small root system; hence the crop is commonly irrigated.

Reaction of soil for celery should probably be slightly acid, although evidence is not conclusive, various writers suggesting ranges from *p*H 5.0 to 7.0; *p*H 5.5 to 6.7 is probably safe.

SOIL MANAGEMENT

Soil for celery should be carefully chosen, as indicated above. Any sod or green manure that is plowed under should be well covered and should be given time for decomposition. The land should be thoroughly prepared.

Fertilizer practice varies widely, but heavy applications are usually made, sometimes as much as 2 tons per acre. On upland soils equal amounts of the three major elements may be used, 100 to 150 pounds of each. On muck in New York a ton of a 1–2–3 ratio is commonly used. The recommendation for muck in Michigan calls for 1,200 to 1,500 pounds of a 3–12–15 analysis.

Side dressing with nitrogen after plants are set is common practice. Shortage of nitrogen appears in slowed growth and yellowing of foliage, but one should not wait until symptoms are pronounced; also other conditions may produce the same symptoms.

Boron deficiency in celery is not uncommon; it appears as horizontal cracks in the leaf stalks or petioles with brownish mottling of leaves. Purvis and Ruprecht [2] recommended 10 pounds of borax per acre applied as spray. It is often added with commercial fertilizer, 10 to 20 pounds per acre, occasionally more in "leachy" soils. Care must be taken to avoid overdose.

VARIETIES

A good variety of celery should possess the following characters:

1. Vigorous growth.
2. Large, thick-fleshed petioles or leaf stalks.
3. Full heart consisting of many petioles.
4. Petioles tender, succulent, relatively stringless, sweet, of delicate characteristic flavor.
5. Fusarium resistant if in an infested area.

Celeries fall into two groups, self-blanching and green. Varieties of long ago were all green. Golden Self-Blanching was found

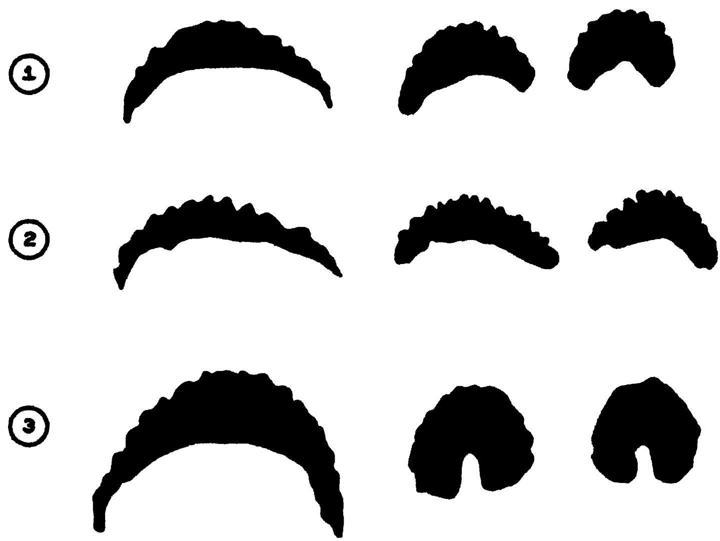


Fig. 25.1. Cross sections of varieties of celery. 1. Golden Self-Blanching. 2. Golden Plume. 3. Giant Pascal, now represented by the Utah's. Note the thick meaty stalk of Pascal. Prints are made by cutting stalks, touching to mimeograph ink thinly spread on glass, and making impression on mimeograph paper. A good laboratory exercise.

as a rogue in Giant Pascal and became very popular. Of more recent years the high quality of green varieties is newly appreciated and they have now outstripped the Goldens in commercial importance.

Golden Self-Blanching was formerly a single variety, but many variations have developed, of which the most important are **Dwarf Golden** and **Golden Plume.** There are many strain names for these and some names that are mere synonyms. The Golden group is characterized by light green foliage, vigorous growth, early maturity, many leaf stalks or petioles, and a well-developed heart; leaf stalks are generally thin, sharply ribbed, and stringy and are readily blanched to a light golden yellow. Table quality is inferior. **Michigan Golden** is resistant to fusarium.

The **Pascal** celeries include **Giant Pascal, Utah** or **Salt Lake, Summer Pascal,** and others. These varieties are late, dark green in foliage, with medium to good heart. Leaf stalks are round, thick and fleshy, smooth-ribbed, tender, not stringy, and green in color, blanching slowly. Quality is excellent. **Utah,** of which there are several strains, shows a heavy heart, lack of which is a weakness of the old Giant Pascal. **Summer Pascal** is more slender in heart but more easily blanched than Utah. **Emerson Pascal,** marked by very finely cut leaflets, is moderately resistant to the leaf blights, and of fine quality.

Cornell 6 and **Cornell 19** were selected from a cross made some years ago by Swarn Singh, a graduate student from India, using inbred Golden Self-Blanching and a strain of Utah. It may be described as a self-blanching Pascal with much of the high table quality of the best green varieties. **Cornell 619** combines the merits of the two, and is fusarium resistant.

SEED

What we call the seed of celery is really a fruit. It is small and the embryo is minute in size and relatively undeveloped or rudimentary. Accordingly germination is slow and weak. Vitality persists for many years under favorable storage conditions. Work found 50% germination in one sample 15 years old. There are over a million seeds per pound.

GROWING PLANTS

Celery is almost always transplanted to the field, though there is some field seeding in the west. Plants for early setting in the north are grown under glass, following the method used for cabbage. Seed is sowed 8 or 9 weeks before field setting. Muckland growers often use sash houses with ground beds of muck. Some broadcast the seed thickly; others plant in rows, which is the better practice.

It takes 30,000 plants for an acre at 6 inches by 3 feet. Two ounces of seed is ample for plants for an acre, and more is frequently sowed in outdoor beds.

As moisture is not easily controlled in ground beds of muck, plants are often soft and too large; when they are transplanted they wilt and get a poor start. The grower is tempted to prune the leaves, which is a practice to be avoided if possible.

During their growth, plants must not be exposed to cold. Temperatures of 40° to 50° F. are likely to occasion premature seeding.[3] See page 106.

Plants for the late crop in the north and for southern crops are usually grown in open beds. The soil should be fine, friable, and well prepared. Rows are 4 to 12 inches apart, as is convenient. Seed is usually sowed too thickly; 25 to 35 seeds per foot is ample if conditions are favorable. It is covered lightly, often by sifting soil over the seed. Since the seedling is small, weak, and slow in developing, care must be taken that the surface soil does not dry out until plants are an inch high and the root system has extended into the soil. This is accomplished by covering beds or flats with burlap, which must be removed as soon as seedlings emerge. When plants are started in midsummer in the south, shading may be necessary.

FIELD SETTING

The celery plant has a very low, disclike stem or crown, and so it must be set accurately for depth. If it is set too deep, soil gets into the heart and may damage it; if too shallow, roots are exposed, and the plant will not stand up. Level culture is usual, but beds of two rows each are common under furrow irrigation.

Plant beds should be well moistened before plants are pulled, and roots should be loosened. Setting is preferably done when soil and air are moist, but, if irrigation water is available, plants may be set under rather adverse conditions.

Spacing. Rows of late celery are commonly 3 feet apart with plants 6 inches apart in the row. Muck celery is now grown under what is called close culture, with rows 18 to 24 inches apart. This accomplishes sufficient blanching for storage and even for immediate market. In frame culture as practiced in Orange County, New York, and near Norfolk, Va., plants may be spaced 11 by 6 inches, that is 6 lengthwise rows per frame.

Setting. Celery may be set by hand, using a dibber or trowel, or by a large field transplanter, provided that it can be drawn slowly enough, or by means of special self-powered machines. See Figs. 11.9 and 11.10. Two men on a machine can set 30,000 to 50,000 plants a day. A dropper and two setters working by hand will do well to set 15,000 to 20,000 plants a day.

CULTURAL CARE

Celery, lettuce, onions, and other low-growing crops suffer drastically if weeds are tolerated. Chemical weed control for any but seedling celery is not recommended.

Thompson (see ref. 10 in Chapter 12) found that celery is one of the few crops that give better response to cultivation by stirring the soil than by scraping; that is, the advantage of a soil mulch in moisture conservation was apparent.

The root system of celery is of limited spread and depth, hence the moisture content of the soil must be well maintained, and irrigation is a major requirement. The muckland crop is often grown without watering, but even on these soils, with their great water-holding capacity, irrigation increases yields and improves quality. On mucklands the level of the ground water may be raised by means of dams or ditches. Overhead sprinkler systems are widely used.

More frequent waterings are required than for crops with a wide and deep root system. Waterings should be thorough, but overwatering may reduce yields materially. Advice on the amount and frequency of watering cannot be reduced to rules. The grower must learn to watch his soil and his plants and to note results.

BLANCHING

Blanching refers to the disappearance of the green color in celery, but special measures for this purpose are seldom practiced as was true in the past. When grown under close spacing, color in the leaf stalks does not develop prominently, nor is it undesirable in the green varieties. Ample moisture and nutrients, along with other conditions favorable for rapid growth, contribute to fine table quality.

DISEASES AND INSECTS

Diseases

Blights of celery include early blight, caused by *Cercospora apii,* late blight, *Septoria apii,* and bacterial blight, caused by *Bacterium apii* or *Pseudomonas jaggeri.* These organisms damage foliage, injure appearance, retard growth, and impair keeping quality. They winter over in celery refuse in the field and are also seed borne. Emerson Pascal is resistant.

Control consists in the selection of a disease-free seedbed and in faithful spraying or dusting in seedbed and field. Bordeaux, insoluble copper dusts, or carbamates are recommended. Seed treatment is necessary unless seed is over a year old, using hot water (30 minutes at 118° F.) or formaldehyde (½ ounce to 2 gallons of water) or bichloride of mercury (1 to 1,000) for 30 minutes. Seed should be presoaked in warm water for 30 minutes before the formaldehyde and mercury treatments.

Fusarium wilt, or yellows, is caused by *Fusarium apii,* which, like other fusaria, harbors in the soil, invades the conducting or vascular tissues of the plants, causes yellowing of leaves, and stunts growth. Control is achieved by the selection of fusarium-resistant varieties. Michigan Golden, developed by Nelson of Michigan, is one of these. Other varieties, including Cornell 619, show different degrees of resistance.

Sclerotinia or **pink rot,** caused by *Sclerotinia sclerotiorum,* is a pinkish, moldy growth at the base of stalks which may be responsible for field and storage losses. Long rotation and low-temperature (31° F.) storage are recommended. Other rots caused by the fungi *Phoma* and *Botrytis,* and **bacterial soft rot,** are sometimes destructive, and control is about as indefinite.

Black heart or **tip burn** is physiological and appears as blackening and dying of tissue in the heart of the plant. It is severe in hot drouthy weather.

Insects

Tarnished plant bug, *Lygus pratensis,* is a sucking insect about ⅕ inch long, variegated brown in color. It stings leaf stalks of celery at the joint or point of branching, apparently injecting some material toxic to the plant tissue. Darkening, known as black joint, and, later, soft rot cause serious damage. Control

is by dusting with DDT or very fine sulfur and hydrated lime in equal parts.

Celery leaf tyer, ***Phlyctaenia rubigalis,*** is a serious foliage-eating enemy in Florida, California, and Michigan. A dust of pyrethrum with ground tobacco or sulfur or lime kills many tyers and drives others out of the webs. A second dusting a half hour later slays the enemies that are then caught without shelter.

MARKETING

Celery is mature as soon as plants are large enough to be salable at a satisfactory price. The hearts or inner leaves of celery enlarge rapidly as the plants mature; this is an important point except on the earliest harvest.

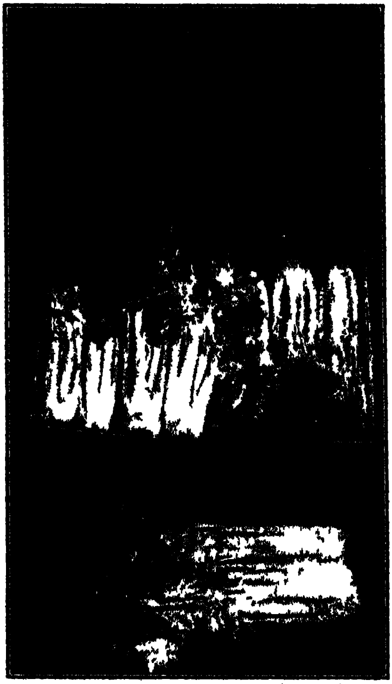
Cutting. Celery is usually cut, on a small scale with a wheel hoe; on a larger scale with a sharp, U-shaped bar mounted on a little tractor, which runs beneath the roots. Tops are sometimes machine-trimmed in the field. Stalks are then lifted, trimmed, and packed into crates. The use of strong, durable field boxes is common. The 16-inch celery crate is used if celery goes to cold storage.

Packing-house methods. Most celery now goes through a packing house where it is further trimmed, washed, sorted, and packed. The machine for the process (see Fig. 25.3) consists primarily of a wire mesh belt, as much as 60 feet long. Celery, as trimmed, is laid on the belt, which carries it through a wash chamber where spray from above and below removes soil.

One concern makes a small belt and spray washer for market gardeners. Another small washer, made to be set on the edge of a large tub, consists of a pair of cylindrical brushes rotating toward each other. On a small scale celery is washed either by hand or with a brush, in a tub.

Packing. After having been washed, celery is taken from the belt and packed by sizes, commonly in a crate of wire-bound veneer (Howard crate) or a sawed lumber crate, in which the stalks are packed in layers with much of the foliage removed and with tops and butts in layers in alternate reverse position. See Fig. 25.2. This fully protects the celery as tops do not protrude.

Larger packing lines include a lidding machine, and the finished crate passes through a small chamber where the celery receives a final rinse. During warm weather, crates may be passed through a tank of very cold water for precooling purposes.



Package Research Lab.

FIG. 252. Howard wire-bound crate, and its nailed counterpart, with alternate reverse pack, save freight and protect celery far better than old-type crates that expose the tops This is a good strain of Golden Plume.

Wrapping celery. The older method of marketing was to ship celery rough or unwashed Jobbers and grocers would then trim and wash it for retail sale. Even under the present system of washing at the shipping point, most celery is further trimmed and again washed at the terminal market. The major cause of deterioration is loss of weight and wilting due to evaporation. Work [8] found that, the greater the coverage of celery by paper, the smaller the weight loss, and he suggested an over-all wrap which, however, would be rather expensive and would conceal the goods. M. R. Ensign found that trimming away of leafage

Washing and sorting celery

FIG 25 3 Celery is brought from the field and is placed on a conveyor belt which carries it through a chamber to be washed by a strong spray.

FIG 25 4 When the above process is finished the workers take the celery off the belt and pack crates of various sizes designated by dozens This is the New York $\frac{2}{3}$ crate, now seldom used for shipping. Celery thus packed is poorly protected.

was important in reducing loss; Work found this more important than wrapping. Wrapping also has advantages in dress-up or display value and in protection against dirt, infection, and mechanical injury. It provides a good way to carry a trademark and directions for use to the housewife.

Some repackers use a paperboard tray which, with the celery, is overwrapped by machine with cellulose film. Much celery is sold at retail without benefit of any wrap.

STORAGE

Storage for market is not practiced as commonly as it was formerly. Florida and California ship newly harvested celery from November on, so that northern celery is now seldom held beyond January.

Celery requires more care in storage than the root crops, and it must be sound and free of disease. For home use it may be trenched on a small scale as described below or it may be kept in a box in a cold, moist cellar or storage cave. It is lifted, roots on, and set as closely as it will stand in a box, with moist soil packed about the roots. To keep it from drying out and wilting, the air must be kept sufficiently moist by covering the box or by sprinkling occasionally. Temperature should be as near 32° F. as possible. Under favorable conditions celery can be kept until late winter.

Cold storage. Most stored celery is kept in refrigerated buildings, usually in the old New York 16-inch crate. The crates are stacked accurately, ceiling high, with spacers between layers and with about 2 inches allowed each way for air circulation. If a storage room is packed full, there is little trouble from wilting. If the temperature of the refrigeration pipes fluctuates widely, drying out will be more rapid. Temperature is as near to 32° F. as it can be held. Thompson [4] showed that the temperature in the middle of the crate is higher than that at the outside and higher than that of the air. This finding led to the substitution of the 16-inch for the 24-inch crate. Temperature is also lower near the floor than at the ceiling. The actual freezing point of celery is about 30° F.

Trenching celery requires less cash outlay but involves more labor and risk than cold storage. It is the old method of market

gardeners and is still followed by a few. Growers of green celery for shipment in Utah and Colorado practice it with good results.

1. Dig a trench 12 to 18 inches wide in a well-drained place, deep enough to set the celery with tops extending not more than a few inches above the surface.
2. Dig the celery, roots on, and set the plants in the trench as close as they will stand, packing earth about the roots.
3. Cover with boards or roofing paper.
4. As the weather becomes colder, prevent freezing by adding straw, leaves, or coarse manure with enough soil to keep the cover from blowing away.
5. Be prepared to remove the cover or to add more according to the weather, striving to keep the temperature between 32° and 38° F. More celery probably is lost from too high temperature than from freezing.

CONCERNING CELERY

Food use

Celery is low in carbohydrate, medium in ash or mineral, and low in vitamins. It is esteemed for its flavor and texture rather than for nutritive value. More celery is sold for use as an appetizer than for any other use. It is delicious when cooked and served with butter or creamed; cooking of outer stalks should be encouraged. Trimmings from city celery-washing rooms are commonly sold as soup celery. The seeds are used as a condiment or flavor. Celery is not canned or frozen, but it is dried and powdered in limited quantity.

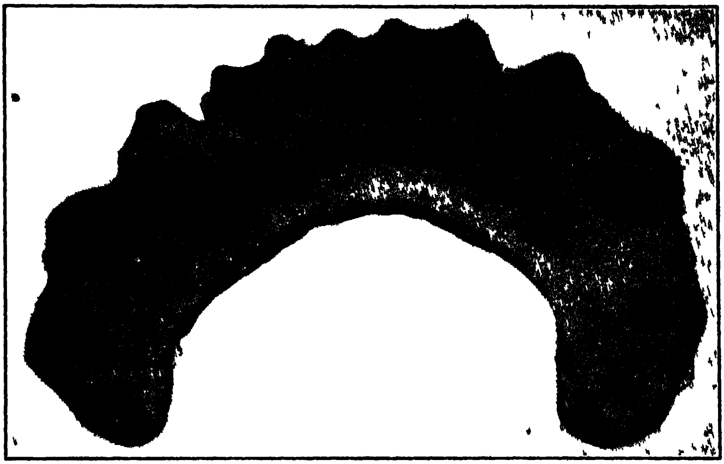
Botany

Celery, *Apium graveolens* (L., *apium,* parsley; *grave olens,* heavy-scented) belongs to the family Umbelliferae (L., *umbel,* little shade; *fer,* carry). The family name comes from the characteristic umbrella-like inflorescence, the umbel. The family embraces a number of weeds, some poisonous, including the coarse wild parsnip and the wild hemlock. The vegetables are carrot, parsnip, parsley, celery, and several of the garden herbs.

The root system of celery is shallow and narrow, but fibrous and dense. It cannot be considered a "good forager" for either water or nutrients, which of course enter the plant together.

The stem is a lens-shaped disc, until it begins to lengthen for seed production, with leaves arising very close together, the inner ones making the heart. The stem, after elongation, is fluted, as is characteristic of the family, and it becomes hollow. The plant in bloom is 3 to 5 feet high.

Leaves, which make up the edible part of celery, consist of a fluted or ridged petiole or leaf stalk bearing branches, usually



After Curtis Cornell University

FIG 25 5 Cross section of celery petiole or leaf stalk showing collenchyma (C) and vascular strands (V), responsible for stringiness. P = parenchyma.

triple, at the joint and palmately arranged leaf blades. The leaf stalk itself is improperly called a rib, a term which should be applied only to the corrugations of the leaf stalk.

The edible leaf stalk consists of epidermis, parenchyma, a strand of thick-walled collenchyma cells in each rib, and a series of vascular bundles. Stringiness of celery, according to Esau,[5] is traceable to both the vascular bundles and the collenchyma strands, although Sayre[5b] in a careful study attributed it to the collenchyma, considering the bundles less significant.

Pithiness in celery represents the breakdown of the thin-walled parenchyma cells that make up the bulk of the leaf stalk. Emsweller[6] distinguished between two types of pithiness, one clearly hereditary, the other presumably affected more definitely

by environmental conditions. The hereditary type affects all petioles of a plant and may be eliminated by careful breeding. Strains vary in susceptibility to the second type, which is to be found chiefly in the outer leaves and develops as the plants mature.

Pollination is largely by selfing within the umbel. Protandry, or maturing of stamen before pistil, generally prevents selfing of individual flowers. Artificial crossing is feasible but is tedious and delicate work, requiring the removal of unworked flowers and of stamens from female flowers.

Breeding

The breeding of celery has been largely on a selection basis. Golden Self-Blanching is said to have appeared as a rogue in Giant Pascal. Nelson and associates selected a fusarium-resistant strain of Golden Self-Blanching, Michigan Golden. See page 473.

Seed production

Celery seed comes chiefly from California. Plants are grown late in one season; they are wintered out of doors and go to seed the next spring.

In the north it is possible to harvest celery seed in August or September from plants which are started in December in the greenhouse, subjected to cold treatment in frames, and set in the field in May.

Importance

Celery has increased rapidly in commercial importance in the past two or three decades. It is of secondary importance as a home garden crop, because in many regions it is not easily produced but is easily bought. It is a crop for intensive culture and high specialization, as distinguished from potatoes and cabbage.

Yields

The average country-wide yield per acre is over 600 crates carrying about 60 pounds. The average for the California second early crop has been over 1,200 crates in 1951 and 1952.

History

Celery was probably known and used in classic times, but the names of plants belonging to this family are confused in ancient literature. Some plant of this sort was taken from wild growth and used for medicinal and ritual purposes.

The earlier herbalists did not comment on celery, but its place as a garden plant was recognized in the seventeenth century and it gained rapidly in use.

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26

Lettuce

Lettuce is the great salad vegetable of the American people. The rapid growth of the lettuce industry is evidenced by the fact that since the 1920's both acreage and production have increased four- or five-fold. Lettuce ranks third among the vegetables in dollar value, coming after Irish potatoes and tomatoes. Lettuce had a farm value of about $125 million in 1952. California planted about 60% of the 212,000 lettuce acres in 1952, and Arizona, 20%. Texas was third with 12,000 acres; no other state exceeded a 5,000 acre lettuce planting.

Lettuce is sensitive to unfavorable conditions of soil and season but it is grown at appropriate seasons almost everywhere for home use and local market. Production for shipment is localized, highly specialized, and mechanized.

For the home garden, there are varieties of lettuce which withstand widely varying conditions so that the product is available during many months practically everywhere. Although markets demand solid head lettuce, leaf lettuce is excellent food and even higher in nutritive value than the blanched heads, a fact that was recognized in 1942 when the government placed head lettuce among "non-essential" crops in planning goals for 1943.

ADAPTATION

Climate. Lettuce thrives in cool weather and demands ample moisture. Crisp-heading lettuce of the Iceberg group is most sensitive to heat, butter-heading varieties of the Boston group are moderately sensitive, and leaf lettuce is least sensitive. Quality in any lettuce is largely a matter of succulence and hot or dry conditions result in toughness and bitterness. Low temperature and slow growth are favorable for good heading. See page 108. When young, lettuce will endure considerable frost;

well-hardened plants may be set out as soon as the ground can be made ready. Head lettuce, as it nears maturity, is readily damaged by severe freezing, but it withstands light frost fairly well.

Soil. Lettuce does well in almost any type of soil that is well loaded with organic matter and nutrients and retains moisture well. Muck soils are widely used in the north and they are being tried out in Florida. The soils of the great producing areas of Arizona and California range from sandy loam to silt loam, the heavier soils being preferred in the warmer seasons.

Lettuce is grown on muck soils only in cool seasons and in cool areas. For example, Ohio muck is heavily planted to onions and potatoes. Celery is raised in south Michigan and lettuce chiefly in the cooler areas and seasons of New York and northern Michigan.

SOIL MANAGEMENT

Reaction of soil for lettuce may well range from *p*H 5.5 to 6.7 on upland; 5.2 to 5.8 on muck. There is danger from manganese and other deficiencies if *p*H is too high.

Organic matter in lettuce soil, all writers agree, should be high. In the Salinas area of California much manure is bought, composted, and spread on lettuce land. A. A. Tavernetti, county agricultural agent of Salinas County, recommends about a ton of organic matter for each 100 pounds of nitrogen applied for maintaining proper balance in lettuce soils.

Fertilizer recommendations vary widely, and local advice should be followed. On new muck nitrogen is seldom required. On land in which fertility is well maintained, lettuce may serve as something of a catch crop, using residual nutrients; but these residues should not be relied upon wholly or without good evidence that nutrients already present are sufficient. An inadequate supply of nutrients reduces both yield and quality.

For a starting point on mineral soils, one may use manure at 10 to 20 tons per acre, and 60 to 80 pounds each of nitrogen and potash, with twice as much phosphoric acid. After extensive experiments in New York, Knott recommended, for lettuce on new muck, 100 pounds each of phosphoric acid and potash, adding 40 pounds of nitrogen if the muck is of reed or sedge

origin. Later in the history of an area, 30 pounds of nitrogen, 120 pounds of phosphoric acid, and 60 pounds of potash are suggested. Oversupply of nitrogen may result in very rapid growth and tip-burn. Undersupply of nitrogen is also dangerous, especially if leaching is serious.

Preparation of soil. As lettuce seed is small and germination relatively weak, thorough preparation of soil is needed to insure even come-up. Western farmers seem careless on this point, but they usually get a crop.

In irrigated sections beds are made up, about 20 inches wide on top and 40 to 45 inches center to center. These beds carry two rows of lettuce, planted near the edges of the beds. Land should be well leveled so that irrigation water will distribute evenly without flooding the rows.

VARIETIES

Lettuce varieties may be classified as: (1) crisp-heading; (2) butter-heading; (3) loose leaf or non-heading; (4) Cos or Romaine.

Most of the commercial lettuce is Imperial, which is sold as Iceberg. There is a distinct variety called Iceberg, but it is not used in large-scale commercial production.

The **Imperials** are crisp-heading varieties, large and vigorous in plant growth, and with somewhat crumpled leaves that have a slightly ashy cast in the green color. The head varies somewhat in shape from slightly flattened to slightly oblong. Under favorable conditions heads are large and solid.

There are now a great many strains of lettuce varieties. Imperial was developed by the late I. C. Jagger and T. W. Whitaker[4] of the U. S. Department of Agriculture. Numbered strains are resistant to brown blight, and lettered strains are in addition more or less resistant to mildew. Important strains are New York 12 and 515, Imperial F, Imperial 847, and Imperial 44. **Great Lakes, 456,** and **Pennlake** are newer varieties for summer, offering resistance to tip-burn, and better heading when conditions are unfavorable. Great Lakes is now of major importance in California.

White Boston is the leading butter-heading variety, characterized by smaller plant and smaller heads than the Iceberg group and by leaves that are less crisp and somewhat oily to the touch. Some consider its quality much superior to that of the Iceberg group. It is a little more tolerant of heat.

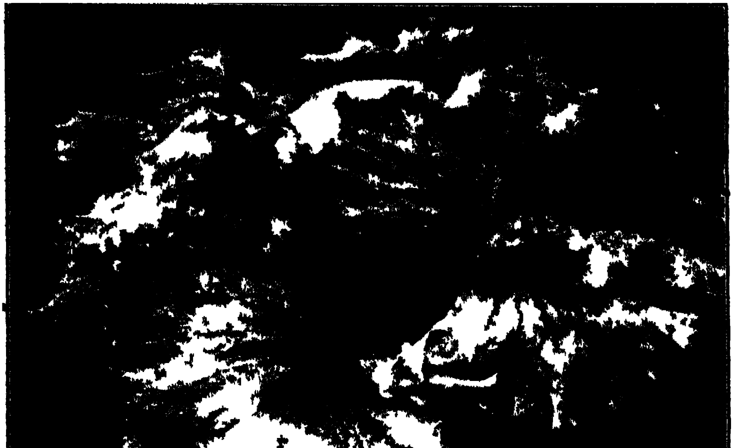


FIG 26 1 Lettuce 456, of crisp-head or Iceberg group, selected for northeastern conditions

FIG 26 2 White Boston, butterhead group

Simpson is the most widely grown leaf or non-heading lettuce for home garden and local market. It grows vigorously, develops a full cluster of green leaves, is savoyed and frilled at the edges, and is of fine table quality.

Grand Rapids is more markedly savoyed and frilled, and is widely used in greenhouse culture. **Slobolt** is a strain that resists heat and the tendency to run to seed. **Oakleaf** and **Salad Bowl** are other good leafy varieties.

Matchless (Deer Tongue), Mignonette, and **Bibb** are heading or semi-heading varieties, of fine quality for the home garden. The first two are resistant to heat.

Cos lettuce or **Romaine** has long narrow leaves, with heavy midribs, which stand erect and form a compact but not a hard head

GROWING EARLY PLANTS

Early plants of lettuce are grown under glass by the same methods as early cabbage plants. Seed must be covered and watered more carefully than cabbage. Plants are readily harmed by overwatering, especially if the temperature is high, resulting in tender, spindly growth.

PLANTING

For home use, lettuce may be sowed in the north from the time the ground is ready until six weeks before hard freezing, the latest planting providing small leaves for the salad bowl. Head lettuces of the Iceberg group require 8 or 10 weeks from seed, about 6 weeks from plants. In most years, in much of the northern territory, Iceberg varieties will not head well later than June; hence early setting of plants is desirable. Farther south, advantage must be taken of the parts of the year that afford suitable conditions for the crop.

The same principles govern commercial plantings. The Salinas-Watsonville area, which ships over 25,000 cars per year, moves little lettuce in midsummer and little in midwinter, but it enjoys two rather long harvesting periods. Imperial Valley and Arizona ship during the winter and early spring months.

The rows for small leaf lettuce in the home garden are usually 8 to 18 inches apart; those for tractor cultivation, either level or on two-row beds with irrigation furrows between pairs of rows, are about 20 inches apart.

Many home gardeners like to sow 25 or 30 seeds per foot, thinning out and using the little plants for salad while allowing others to grow. Otherwise 6 to 9 seeds per foot are sufficient in most soils. Leaf lettuce for market should attain good size with leaves 6 to 10 inches long. Spacing of 8 inches in the row will give well-developed bunchy plants. Boston lettuce is well spaced at 10 to 12 inches in the row and Iceberg at 12 to 16 inches.

Commercially seed is usually planted with small garden drills, singly or in gangs. In most soils, ½ inch is a suitable depth. An acre requires 1½ to 2 pounds of seed at ordinary spacing.

Common practice in thinning is to chop spaces in the row with a hoe, leaving one or more plants at each spot. The job is then finished by hand. Doubles among head lettuce generally result in two unmarketable heads.

Transplanted plants are set by hand or machine. Care should be taken to place them at the proper depth, with crown at soil level. Deep setting seems to favor development of tall, pointed heads.

LATER CARE

As lettuce cannot successfully compete with weeds, thorough but shallow cultivation is required. Most of the eastern muckland lettuce is not irrigated even though lettuce requires ample and constant moisture supply. Irrigation in the east is commonly by sprinkler system; in the west, by furrow. Details of watering must be varied according to conditions, less water being used on heavier soils, with young plants, and when weather is humid. Overwatering is likely to result in pale, soft, spindling growth of young plants and should be avoided as plants near maturity, in the interest of lettuce that is free of "slime," that will carry well, and that will still be of high quality.

DISEASES AND INSECTS

Bottom rot, caused by *Rhizoctonia solani,* is common in the northeast, appearing where outer leaves touch the ground. Later it extends into the head but does not rot off the stem. Control is favored by long rotation and good drainage.

Drop, caused by *Sclerotinia* spp., is more serious in the south than in the north. It begins at the stem next to the soil, killing

the leaves, which are turned into a wet slimy mess. It is characterized by a whitish mold and by dark firm resting-bodies of mycelium, called sclerotia. Rotation and use of copper or tersan dust are recommended.

Gray mold rot, caused by *Botrytis* sp., more common in greenhouse and frames than outdoors, is controlled by dusting with arasan. It is favored by cool damp weather.

Downy mildew, caused by *Bremia lactucae,* is serious in the west, also in greenhouses and frames. It does not endure severe winter cold although it survives in wild lettuce. Imperial D and F varieties are partly resistant, as is a strain of Grand Rapids, known as USDA No. 1.

Yellows, a devastating virus disease carried by insects, causes pale yellow leaf color, malformation of center leaves, and dwarfing of growth. Eradication of host weeds is of value for control. The most effective method is frequent DDT applications to control the leafhopper, which is the vector or carrier.

Brown blight, cause unknown, is serious in the west. Plants are dwarfed, rosetted, and of mottled color, and fail to head. Resistant strains of Imperial, designated by letters, have proved useful.

Tip-burn, a physiological trouble, results in breakdown of tissue at the edges of leaves and later may extend to the very heart of the plant. In spite of considerable study, the conditions causing it are still little understood. It is not, as formerly supposed, primarily the result of failure of moisture to reach the cells of the leaf edges, for it often develops in a humid atmosphere and in the dark. High temperature favors it. There seems to be less trouble when plants do not grow too fast. Some strains seem more resistant than others. Tip-burn is often followed by decay, bacterial or otherwise, called slime, a term which is also applied to *Botrytis* rot.

Insect troubles are not common. Cutworms are controlled with poison bait (page 456), and aphids with pyrethrum or nicotine dust, or, under glass, by fumigation.

HARVESTING AND MARKETING

For home or for market, in large fields or small, lettuce is cut off near the ground and handled as bunch or head. It is mature

Southern Pacific Ry

Lettuce is produced and marketed in the grand manner at Salinas, California

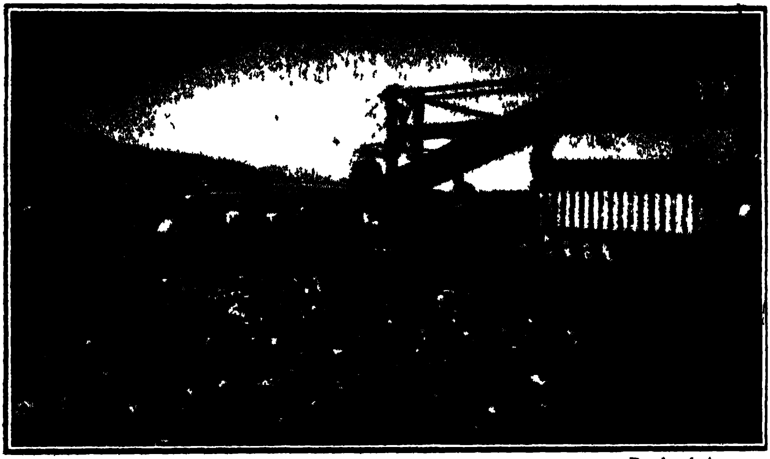
FIG 26 3 Heads are cut with outer leaves and tossed to trailer This trailer has moving conveyor bottom to unload mechanically Huge crates shown in packing-house pictures go to the field, seven on a trailer

FIG. 26 4 At the packing house, crates on casters roll from trailer to packing-house floor and are tilted by air hoist

FIG. 26 5. Trimming and placing on packing table.

as soon as the cutter chooses to take it. Marketers of leaf lettuce find it desirable for plants to grow to good size, 8 to 10 or even 12 inches high. Heads are cut when they reach the size and degree of firmness that the market will accept, a standard that varies with supply and demand.

Much lettuce for local sale is simply cut, placed in used crates or baskets, and then taken to market. Some is washed to remove dirt that may have been splashed on to it and to freshen it



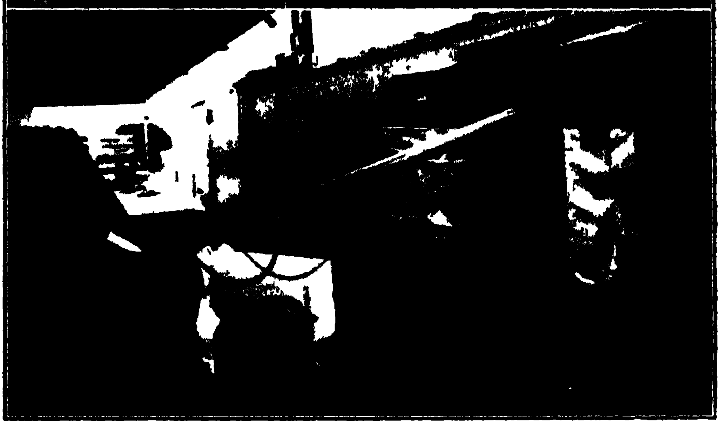
Bank of America

FIG 26 6 Conveyor-loader for harvesting lettuce.

by imbibition, or the taking up of water. Many local gardeners line and cover crates with newspaper and some use waxed or parchmentized sheets. New England gardeners use the Boston box; 18 heads are considered a box whether the heads are large or small. Sometimes ice is placed in the box.

Western shed packing. The large western shippers and an increasing number of eastern and southern growers have adopted shed packing for Iceberg lettuce. There are about fifty great packing sheds at Salinas, California. See Figs. 26.3 to 26.9.

On a large scale, the harvesting of lettuce begins when a tractor with a specially designed trailer sweeps across a field. A group of workers cut the heads at the ground line and toss them into the body of the trailer which is built for mechanical unloading at the packing shed. Some trailers or trucks carry five huge steel crates about 4 feet in each dimension.



Southern Pacific Ry

FIG. 26.7 Packing 48 size in one crate, 60 size in the other. Note wax-paper liner and printed collar.

FIG. 26.8 *a*. Package icing is important. *b* Into the car. Note conveyors widely used in packing houses.

FIG. 26.9 Top ice is crushed and blown into the car. Then she's ready to roll, nine or ten days to New York. Fast reefer freights speed at 60 part of the time, but switching and re-icing cause delay.

At the packing house trimmers remove the butt of the stem and the outer leaves and pass the heads to a narrow table where there may or may not be a rinsing spray. Up to this point the outer leaves have protected the head from handling which is rougher than market cabbage will stand.

Packers stand between two western lettuce crates which are about 13 by 18 by 22 inches inside. One crate is usually for 48 larger heads, the other for 60 smaller ones which are packed in three layers. Two paper liners, waxed or parchmentized, are placed in the crate, then alternate layers of lettuce and ice. Heads are arranged by size so that there is a bulge of 3 or 4 inches. About 20 to 30 pounds of ice is used in a box. The lettuce weighs from 55 to 80 pounds. The crate moves on a roller conveyor to the lidding machine and so to the car where it is stowed, with the bottom parallel to the side of the car. Loads normally range from 288 to 320 crates per car. Bunker and top icing are used as needed, according to season and destination. Much lettuce for nearby western markets is shipped "dry pack," without benefit of packing house or ice.

Packers in other areas use methods ranging all the way from field packing and simple shed packing to elaborate systems. Boston lettuce is too delicate to stand shed packing. It is usually packed in crates 7½ by 16 by 19 inches inside, two layers deep. Eastern growers are using a crate 9 by 17 by 22 inches for Iceberg.

Vacuum cooling is a recent development. Lettuce is trimmed and field-packed in paperboard cartons. See page 57.

Transportation charges consist of a freight rate per 100 pounds, a standard refrigeration charge for bunker icing, and a top icing charge. From Salinas to New York these costs are respectively $2.38 per hundred weight, $80 and $13 per car. At a billing weight of 90 pounds and a load of 300 crates, the cost per crate would be approximately $3.00, which is just about the 1952 average price of California lettuce at shipping point, packed and ready to go.

Platenius [8] has reported on a thorough study of lettuce marketing in New York, where both distance and time are short. His work showed package icing superior to 36-hour precooling in cold storage.

The temperature effect of package icing continues after shipment and helps curb evaporation. The degree of deterioration when lettuce reaches the market increases with time and with temperature.

Lettuce may be kept in cold storage for about a month, at temperatures of 32° to 33° F. and high humidity.

CONCERNING LETTUCE

Food use

Lettuce probably appears more frequently on American tables than any other vegetable except the potato. It is popular for its delicate, crisp texture and slightly bitter tang. It is often served alone or with dressing or with tomato, cucumber, or other salads, such as potato salad. A tossed salad needs celery and garlic, pepper and parsley, but the principal ingredient of it is usually lettuce. Dishes of all sorts are garnished with lettuce; and many a sandwich, up to and including a four-deck toasted club sandwich, is incomplete without it.

The nutritive value of lettuce is high but rests largely upon a good content of minerals and a moderate store of the vitamins.

Botany

Lettuce, *Lactuca sativa,* belongs to the family Compositae, which is last in our botanical list and is presumably the most highly organized and specialized of all plant families. Characteristic of the family is the flowering head which most of us think of as a single flower, but which is really an inflorescence of many blossoms, sometimes of two sorts, disc and ray flowers, as in the daisy or golden glow. Beside lettuce, other vegetables of this family are salsify, chicory, endive, dandelion, globe artichoke, the girasole, often called Jerusalem artichoke, and the herb sage. Some examples of common flowers are chrysanthemum, aster, goldenrod, and marigold.

Pollination is chiefly by selfing, occurring usually before flowers are fully open. As the flower develops, the hairy pistil pushes out through the anther tube, gathering pollen as it goes. This is all a matter of minutes. Technique for controlled pollination was developed in about 1910 by G. W. Oliver of the U. S. Department of Agriculture. Flowers open very early in

the morning, pollen is washed away from the elongated stigma with a fine stream of water, other pollen is applied, and the flower head may or may not be bagged to protect it from contamination.

Seed. What most people call the seed is really a fruit, an achene carrying a pappus of fine silky hairs Germination is

FIG 26 10 Lettuce in blossom Note the composite head, consisting of several ray and disc flowers

prompt and strong in relation to the size of the seed as compared to celery in which the embryo is very small and rudimentary.

Breeding

Our head lettuces of Iceberg type are many in number and have been developed under intensive breeding programs, mostly by I. C. Jagger and T. W. Whitaker,[4] of the U. S. Department

of Agriculture, and their associates. The New York variety was improved and refined, and strains are designated by numbers, such as New York 12. In an effort to control brown blight, this was crossed with a Cos variety, giving rise to the Imperials, of which there are many. Some are at least partially resistant to mildew. These are well adapted to California conditions where the work was done. Workers in New York, seeking strains better adapted to the northeastern conditions, have developed Imperial 44 and a strain that goes by number alone, 456. Great Lakes, a Michigan selection, with 456, has made great headway in the west.

Seed production

Most of our lettuce seed is produced in California, much of it in the Sacramento, San Joaquin, and other interior valleys. Seed is sown in fall or spring, and the seed stalk shoots up and blooms, bringing seed to harvest by mid-summer. Pollination is mostly by selfing. Plants are cut, and seed is threshed and milled like other small seeds. Home saving of seed is not difficult, but seed should be saved only from plants that have made good heads. Otherwise a gardener may be unwittingly selecting for an undesirable character.

Yields, costs, and returns

Lettuce, especially head lettuce, is very much of a gambler's crop, being highly sensitive to unfavorable weather or other conditions. Often heading is not uniform, and marketable yield may be greatly reduced; or disease may devastate a field in a week. The average yield per acre for the country is about 175 western crates of about 70 pounds each, usually 48 or 60 heads.

History

The use of lettuce is recorded more than 500 years before Christ. Its healthful properties were praised by Hippocrates, a Greek physician of 430 B.C., and by Aristotle, 350 B.C., and it was popular in Rome. In America many varieties were catalogued in the early nineteenth century. Its popularity has increased enormously since 1918, when formal production records began.

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27

Spinach

Spinach, the most popular of the pot-herbs or "greens," has had, perhaps, as widespread publicity as any other vegetable. Popeye the Sailor, creation of the late E. C. Seeger of Crystal City, Texas, the heart of the spinach country, has sounded the praises of spinach throughout the country. Doctors have wavered back and forth: first, it's excellent for you; then the availability of its calcium is questioned, and even its influence on the availability of other calcium is maligned. Present opinion seems to be that spinach has high nutritional value chiefly on account of the very high vitamin A and C content. People are using over three times as much as in 1920, chiefly because they like it. A survey of children in New York showed that they proclaimed spinach their favorite vegetable. Over 20 million bushels are used each year; after all, this is only 2½ or 3 pounds per person, and that is not enough for very many meals, six or eight servings for one person.

The majority of fresh spinach is now sold trimmed, washed, and packed in bags of cellulose or other film, a development that has greatly changed the crop picture. Spinach ranks third among the frozen vegetables; considerable quantities are canned.

ADAPTATION

Spinach grows from seed, and the entire plant is cut as soon as adequate size has been reached. It grows to maturity in six to ten weeks, thriving well in cool weather and poorly in hot weather. It goes to seed quickly under certain conditions,[5] discussed on page 108, although slow-bolting strains have been bred. It does not germinate well in hot weather, and continuously wet soil may result in poor come-up. Spinach withstands hard frosts, as low as 20° F., and may be wintered over where climate is as

mild as South Jersey or Maryland. Farther north, a little cover of straw or manure may be needed.

Soils for spinach vary through the widest range, light sandy loams in Virginia and New Jersey, and silty to clay-loam soils in Texas. A good deal of the cannery crop is grown on muck, which is not gritty to the teeth. The canners do wash it thoroughly, whatever the soil. The sandy soils are preferable for early yields. Spinach is not tolerant of acidity or of the aluminum toxicity that may accompany *p*H lower than about 6.0. At the same time manganese deficiency symptoms may develop when soil is alkaline, or even slightly acid, with *p*H higher than about 6.8.

SOIL MANAGEMENT

A high organic matter content is desirable for spinach although much of the crop is grown on light sandy soils. When stable manure is used, it should be well rotted or applied for the previous crop. Green manuring is best done well in advance of spinach.

Fertilizer practice in the east calls for moderate applications, around 50 to 100 pounds each of nitrogen, phosphoric acid, and potash. On sandy soils, top dressings of nitrogen or of a complete fertilizer heavy in nitrogen may be in order. Slow growth or yellowish green foliage may suggest need of nitrogen, although chlorosis may also indicate aluminum toxicity, shortage of manganese or iron, the effect of acidity itself, or virus infection. In Texas, where over a third of our fresh-market spinach is grown, little fertilizer is used, as the crop is commonly raised on new or nearly new land. California, which is the leading cannery state, has used little fertilizer, but evidence supports the value of nitrogen applications. For muck soils 15 to 20 pounds of nitrogen, 60 to 90 pounds of phosphoric acid, and 30 to 45 pounds of potash are suggested.

VARIETIES

Spinach varieties [2] fall into two major groups: savoy leaved, preferred for market; and smooth leaved, for canning. Geise [4] and associates have made careful studies of quality in cannery spinach and have gauged varieties by the standards which they have formulated. Ratio of petiole or leaf-stalk material to

total, waste in preparing, consistency after canning, color, and flavor were among the points considered. Simliar quality analysis has been made for some other vegetables, but much more work along this line is needed.

Bloomsdale is characterized by an upright or vase-shaped plant, with large, thick, heavily savoyed or crumpled leaves of dark green color. Several strains are grown. **Virginia Savoy** is highly resistant to mosaic but runs to seed quickly in the spring. It is widely used for fall planting. It resulted, at the Virginia Truck Experiment Station, from crossing Bloomsdale with Manchuria, which is resistant to mosaic. **Old Dominion** is similar but bolts less quickly. **Long Standing Bloomsdale, Summer Savoy,** and especially the new **America** are of fine type, slow-bolting, and well adapted to summer use.

FIG. 27.1. Bloomsdale group, including Long Standing Bloomsdale (shown here), Virginia Savoy, Old Dominion.

Nobel, or Giant Thick Leaf, is typical of the flat-leaved varieties which are spreading in habit. It is lighter green in color than Bloomsdale and only slightly savoyed, hence easy to wash for canning. Yields are heavy, and growth is rapid. **Prickly Winter** or **Hollandia** is similar in type but has prickly seeds and is widely used for canning in California.

PLANTING

Spinach is planted in the north as soon as land can be prepared in the spring. For fall use, it is sowed in August and September. Farther south, planting times are gauged to permit growth during cool weather.

Broadcast or rows. Broadcasting is still practiced to some extent in Texas, but row-drilling is general elsewhere and is increasing in Texas. When surface irrigation is practiced, and also when rainy weather is probable, raised beds are desirable, of 4 to 6 rows, sowed 8 to 12 inches apart, using gang drills. Spacing of 16 or 18 inches between rows is common in California; a little closer spacing is common in Texas.

Quantity of seed per acre ranges from 4 to 30 pounds, thus affording a wide choice. The smaller quantities are sufficient when soil is moist and cool, when damping off is negligible and if good-sized single plants are desired to meet the preference of most markets. Sowing 15 to 20 seeds per foot is usually sufficient in the home garden. Thinning out of small plants will yield a "mess" of early greens. A thinner rate of sowing for final stand of 4 or 5 plants per foot is good for market spinach. Seed should be treated as suggested under the section "Damping Off," below.

IRRIGATION

In Texas spinach is commonly irrigated by flooding in beds or by the furrow method. The first application follows planting, and the second may be necessary very soon in order to get the seedlings above ground. One to three waterings usually follow. Hawthorn (*Tex. Sta. Circ.* 66) reported reduced yields from overirrigation. Scott [1] cautions against allowing the soil to become dry, since the root system of spinach is limited.

DISEASE AND INSECTS

Damping off, caused principally by various fungi, often reduces stands of spinach, not only by destroying seedlings after they are up, but also by rotting seeds and infecting tiny seedlings below ground. In the latter case, the planter may think the seed is poor. The trouble is more common in warm, wet weather and is controlled by treatment of seed with copper oxide, zinc oxide, or semesan, following directions for the material used.

Downy mildew, leaf mold, or blue mold, caused by *Peronospora spinaciae*, is troublesome when wet weather coincides with cool nights. It shows yellowish spots on the upper sides of the leaves and a dense gray or blue-gray mold beneath. Though copper is toxic to the fungus, its use is not practical. Prickly-seeded, flat-leaved varieties are reported by Scott [1] to be somewhat resistant. Overcrowding favors the disease. Refuse should be plowed under promptly and completely.

Mosaic or yellows, often called blight, is a virus disease appearing as yellowing, malformation, mottling, and dying of leaves.

It is carried by insects, especially aphids. Control is by use of the resistant varieties, Virginia Savoy and Old Dominion.

Curly top of beets, a virus disease, also affects spinach, which belongs to the same botanical family as beets. No suitable control is known.

Aphids, *Myzus persicae,* damage spinach and carry mosaic. Use of parathion or nicotine dust, with a long trailing apron behind the duster, is recommended but is not commonly practiced.

Leaf miner, *Pegomyia hyoscyami,* and, in Texas, **bud worms,** *Hylemia cilicrura,* are maggots of flies damaging spinach. Good controls are not available.

HARVESTING

For home use spinach may be cut as early as one chooses, perhaps thinning out little plants for the table, allowing others to attain full size.

Most markets prefer well-developed, bushy plants, although Los Angeles accepts small, thickly grown plants in little bunches. Cutting for market is usually by hand. Spinach is commonly trimmed of broken or yellow leaves and placed immediately in bushel baskets. When it gets to the car door, in Texas or in Virginia, the cover and a third of the spinach is lifted, and 8 or 10 pounds of crushed ice is slid in. Then, all too often, the spinach is rammed down, the lid is forced to its place, and the basket is thrown into the car—a good example of bad handling. Leaves protrude between cover and basket and are bruised and dried out. Sometimes as much as 30 pounds of spinach goes into a basket, although 12 pounds is a legal bushel in Massachusetts.

The Walla Walla Growers Association in Washington has had good success marketing spinach in 20-pound boxes, 9 by 16 by 18 inches inside. A waxed paper liner and 15 pounds of ice are used. W. A. Langdon of New York uses Los Angeles lettuce crates and commands premium prices; Williams Brothers in Vermont use a smaller box.

For canning, spinach is cut with scuffle or shove hoes, with blades mounted on little sleds, or with a scoop-fork which has been modified to include a V-shaped blade at the middle of the

front edge. Harvesting machines are now in use. The spinach is handled in bulk or in large field crates; it may not be stored for more than a few weeks.

Prepacking of spinach now accounts for a large part of the fresh market crop. At terminal markets spinach is trimmed, sorted, and put through a washer. Part of the water is removed with a centrifugal dryer, such as is used in a laundry. It is then packed, 8 to 12 ounces, in a bag of cellulose or other film. A few small perforations are desirable. Bags are packed in paperboard cartons, and the goods must be thoroughly cooled and kept cool.

Much spinach is cut above the crown and packed as loose leaves for prepack purposes.

CONCERNING SPINACH

Food value

The green and yellow leafy vegetables are emphasized in every plan for better nutritional standards, and spinach and cabbage are the leaders among those that are cooked. Spinach ranks high in minerals and in the vitamins. It is first in MacGillivray's efficiency rating (page 5), and the fact that its calcium is largely unavailable, owing to the presence of oxalic acid, has detracted little from its standing as a valuable food. Its popularity, after all, is based in large degree upon people's liking for it.

Spinach is commonly boiled, best with a minimum of water and for only a short time. It is sometimes creamed or used in soups, and it is finding an acceptable place as a raw ingredient of salads.

Botany

Spinach, *Spinacia oleracea*, belongs to the family Chenopodiaceae or goosefoot family (Gr., *chenos*, goose; *pous*, foot). Here belong the beet and two minor plants used for greens: mercury, or Good King Henry, and orach.

Germination is moderately vigorous but is inhibited by high temperature, say 85° F. The root system is narrow and shallow. During growth to market maturity, the stem is very short.

Pollen is fine, light, and disseminated by wind and gravity. Selfing seldom occurs even on monoecious plants on account of *protandry* (Gr., *protos*, first; *andros*, male) or development of stamens before stigmas are receptive.

Seed-stalk development. See page 108.

Seed production

Seed was largely from Holland until World War II prevented importation. Today it is being successfully grown in the Puget Sound region and in some other areas. Seed matures in a single season, and cultural methods are similar to those for the market crop. When seed is ripe, plants are cut, shocked, dried, and then threshed like grain. The seed crop does not do well in areas where the time between planting and the longest days of summer is too short for full plant growth.

Importance

Spinach is about a $15,000,000 crop. Texas has planted, as a 10-year average, about half of the 80,000 acres grown each year. California, Oklahoma, and Arkansas follow. The great Texas area is in the Winter Garden section between San Antonio and Laredo.

Yields, costs, and returns

The average yield, for fresh market, throughout the country, is about 225 bushels per acre, much lower than in the 1920's, when it was about 350 bushels. These figures probably reflect the fact that lower yields are obtained in Texas than in Virginia since Texas has gained in acreage. The average yield for canning is about 3½ tons per acre. Scott [1] indicates that 5 to 6 tons is average for the better districts, 8 to 10 tons fairly common, and 12 to 15 tons very good. In New York 7 tons is not considered above average for good growers on good farms.

History

DeCandolle represents spinach as new to Europe in the fifteenth century, but Sturtevant cites references to its culture as early as the twelfth century. It is presumed to have come through Africa and Spain. One author cites seventh and eighth century references to its culture in China.

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28

Asparagus and Rhubarb

ASPARAGUS

Asparagus and rhubarb are the only two vegetables of major importance that are perennial. This is a major point to consider in deciding whether or not to grow asparagus. In most of the United States heavy cuttings are not to be expected until the fourth year from seed or the third year from field setting. This is about as long as it takes to bring peaches to bearing. Beds are good for 12 to 20 years or longer.

Asparagus is costly to bring into production but relatively cheap to maintain. Harvesting and marketing occur in spring and early summer when the labor demand is relatively low and when income is most welcome.

Thompson,[1] in his book *Asparagus Production*, makes a strong case for asparagus in the home garden because the product is expensive on most markets, yields liberally in the spring when home-grown vegetables are scarce, is easily produced, and has quality far superior to that of the market asparagus. Home-garden culture follows commercial practices closely, save that operations are on a small scale.

ADAPTATION

Asparagus is thoroughly hardy to cold, at least throughout the United States. It does not thrive from Florida to Texas, but half the nation's acreage for fresh market and processing is in California, mostly in the Delta; New Jersey stands second. The California crop is shipped for a few weeks; the later harvest is processed. Plantings for processing from Iowa eastward have been increasing.

Kimbrough (*La. Sta. Bul.* 270) found little promise in asparagus as a crop for the far south. Plants continue to produce

shoots through summer and fall but fail to store adequate reserves for a spring crop. He attributes failure to this factor

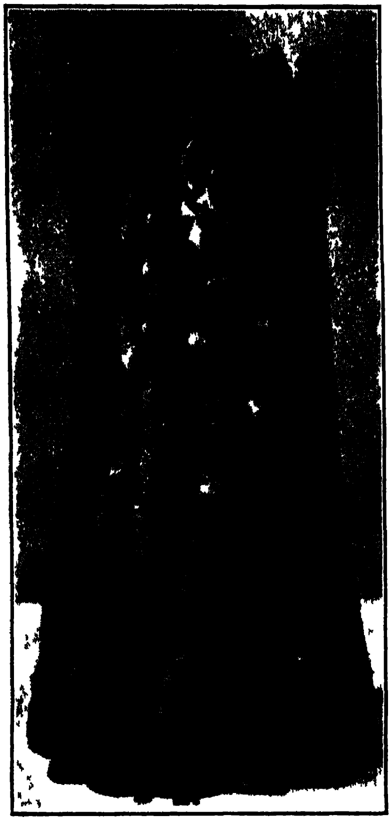

FIG. 28.1. Fine asparagus well bunched and tied with tape. Note uniform size and color, close tips The spear is the shoot of the plant, the growing point and stem before branching occurs.

rather than to lack of a sufficient period of dormancy. The alternation of warm and freezing weather during the winter is another obstacle.

Asparagus requires good drainage and will not endure flooding for much over a month at any season. The soil range is wide, but sandy loam and well-drained muck soils are preferred. Heavy soils are not suitable, nor are soils that are very acid, say below 6.0 in *p*H.

Soil Management

Asparagus occupies the land for a long time. Moreover the growth of one summer makes the material for the harvest of the succeeding spring, and the great root system is the winter storehouse for this material. There has been much argument about when to apply manures and fertilizers. In most situations it makes little difference. Applications before the cutting season have little effect on the current crop; material applied after cutting improves growth and increases stored reserves for the next year's crop.

Organic matter in liberal amount is desirable for asparagus, but it may be maintained by discing down the tops each spring. Wessels and Thompson [4] found that manure plus superphosphate gave lower yields than fertilizer alone during the first four years of cutting but higher yields in later years. However, increases in later yields were not sufficient to justify the extra cost of the manure. If manure is available at low cost, it may properly be used, but on most farms there are other crops to which it may be applied more profitably.

Fertilizer applications should be planned according to local advice and practice. For lighter soils 60 to 80 pounds of nitrogen, 100 to 120 pounds of phosphorus, and the same quantity of potash will serve as a starting point. This would be about 1,500 pounds of a 5–8–8. On heavier soils the proportion of phosphorus may be raised to a 1–2–1 ratio. Experiments in the asparagus district of California have shown little return from fertilizer.

Salt. The old timers said that asparagus, being a seashore plant, must have common salt, sodium chloride. Some experiments have supported the use of salt, but data are not convincing and most asparagus is grown without it.

Varieties

Most of the asparagus grown today is **Mary Washington,** a variety developed 35 years ago by J. B. Norton [9] of the U. S. Department of Agriculture, working in the old Concord, Mass., asparagus section. It is resistant to rust and is of better type and performance than the old Palmetto and Argenteuil which it replaced. **Martha Washington,** also

developed by Norton, is superior to Mary in rust resistance but not in other respects.

California 500, a new strain bred by G. C. Hanna, starts vigorously in the spring, yields well, has tighter heads showing less purple, and is more uniform in size of spears.

Minnesota 4-way Cross, a hybrid by Currence of Minnesota, is reported to yield larger, heavier stalks.

Great differences in yield and type among individual plants have been noted, and various workers are developing improved strains of considerable promise.

Plants

Good plants are very important in establishing an asparagus bed which may be harvested for over a decade or two. Most nursery plants have been so crowded that they are small and weak. Myers [5] showed in 1915 that medium- and large-sized asparagus roots materially increased yields during the first six harvest years. His findings have been supported by others. Crowns should weigh from 50 to 125 pounds per 1,000.

One-year-old crowns are better than two-year-old plants, and they are dug and reset with less damage. Two-year-old roots do not, as sometimes claimed, give heavier yields in the earlier harvest years.

Male vs. female plants. Experiments by Hanna [3] and others have shown that female plants give more spears and larger yield per acre than male plants. There is difficulty in recognizing the sexes in year-old plants, and the practice of sorting for sex is not followed, even in California, where a single year's growth brings plants to bloom.

The program for starting an asparagus bed is about as follows:

1st year	Sow seed.
2nd year	Set in permanent bed.
3d year	Do not cut except where growing season is very long.
4th year	Cut for half a season, about 4 weeks.
5th year	Cut for full season, about 8 weeks.

Full yield will not be reached until a few years later. A home garden planting may be based on 8 to 15 plants per person.

Asparagus seed germinates slowly, especially at low temperature. Borthwick in California found that growth can be hastened

by soaking seed for 3 to 5 days at 85° to 90° F. The effect is due to hastening the absorption of water rather than to breaking dormancy. Seed should not be soaked to the sprouting stage, and it should be dried slightly before sowing.

Plant beds should be well fertilized and well prepared. Rows may be spaced 15 to 24 inches apart as is convenient. For really good plants, seed should be 2 to 5 inches apart, a spacing which

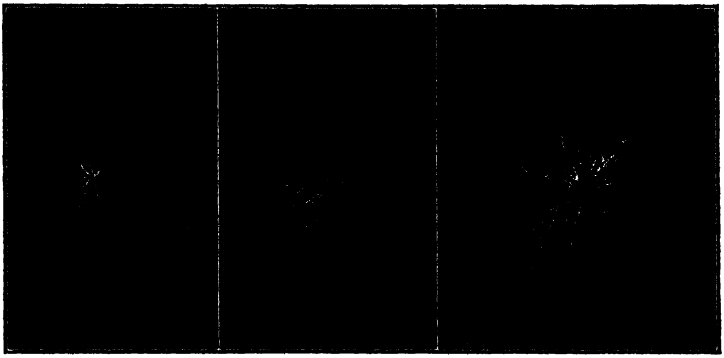

FIG. 28.2 Young asparagus roots. *a*. Too small, 20–25 pounds per 1,000 roots (40–50 per pound). *b*. Good size, 50–60 pounds per 1,000 roots (15–20 per pound). *c*. Many prefer extra large roots, 125–150 pounds per 1,000 (6–8 per pound). These start strongly and give much better results than *a*, somewhat better than *b*.

requires about 3 to 5 pounds of seed per acre of plant bed. This should easily produce plants for 6 or 8 acres of asparagus. Most plant growers sow seed much thicker.

Weed control is the principal care during growth. In most climates, irrigation is a good investment; in some, it is essential.

Digging of crowns is best postponed until spring so that there may be little drying out. They should be removed with minimum breakage of roots. If crowns must be stored over winter, the temperature should be low, about 35° to 40° F. There should be moisture enough to prevent desiccation but not enough to favor decay.

Permanent Planting

Preparation of land may well begin two years ahead of setting, growing crops with which weeds are well controlled, gradually deepening the soil if necessary, and building up organic matter

and nutrients. Heavy cover crops should be plowed under long enough ahead of planting to allow for fairly full decay of the plant material. Otherwise furrowing and planting will be interfered with.

Spacing and planting. Rows are generally 4 to 5 feet apart with plants 18 to 21 inches apart in the row; they are wider in California or wherever soil is very rich and fertile. Close spacing makes for heavier yields during early years; wide spacing, for longer life of the bed if other conditions are favorable.

Furrows are plowed out so that roots will be covered with 6 to 8 inches of soil. The furrow should be wide enough to allow reasonable spread of roots, and there should be loose soil in the bottom.

Plants are covered only 2 or 3 inches deep to avoid smothering; then soil is gradually worked in as the season advances, a practice which helps in weed control.

As an asparagus bed is set to last for years, Somers (*Ill. Circ.* 507) emphasizes the importance of a good stand. It costs about as much to maintain a 75% stand as a 98% stand. Most common causes of "skips," he says, are poor choice of land, poor soil preparation, weak or dried-out plants, and badly damaged crowns, especially those that have lost their only buds. Most of these troubles can be avoided by: (1) growing or buying good plants, (2) selecting rigidly, (3) planting with care, especially avoiding too deep covering. Skips should be filled the next spring with strong plants.

There is some support for the idea of shallow planting, especially for home garden, and on heavy soils.

Cultural Care

Weed control is a serious problem with asparagus because the bed is perennial. Thorough row cultivation should be practiced during the cutting season, but it becomes increasingly difficult as the crowns spread. The spring-tooth weeder, used in the afternoon when spears are slightly wilted, is effective and does little damage. After the cutting season the bed may be harrowed or disced thoroughly, but not deeply. Some cultivation may follow during the period of top growth, and some hand work may be required to prevent weeds from going to seed.

Calcium cyanamid (22% nitrogen) is a good nitrogen fertilizer and a valuable weed killer. It may be broadcast at the rate of 200 to 400 pounds per acre or placed in a band 18 inches wide over the row. After cutting season, another application of 100 pounds per acre may be made over the row when weeds are small and when they are wet with dew or rain.

Control of broadleaved weeds, but not of grasses, by means of 2,4-D is successful. It is used before and after cutting season, in the latter case avoiding spraying the tops.

Irrigation is not common in humid regions since the plant has a deep and extensive root system. In the asparagus areas of the California Delta much of the land is below river level, and irrigation is done by raising the water table in ditches. Surplus water must be pumped out. Some land is irrigated by furrow. Two irrigations during the cutting season and two afterward are usually sufficient.

Tops should be left as they are until spring, when they may be disced into the soil. Removal or burning of tops is of little protection against disease because plenty of infected material falls to the ground. The tops are valuable for soil organic matter. An old bed on sandy soil at Ithaca, N. Y., treated in this way remained greatly superior to adjoining land in organic-matter content and tilth for a number of years after it was plowed up.

Diseases and Insects

Asparagus rust, caused by *Puccinia asparagi,* has been serious at various times and places, but the Washington varieties are generally resistant. This disease seems to come in waves, and some growers think that reselection for resistance may become necessary in seriously threatened areas. Sulfur dust is of some value for control.

Asparagus beetles, *Crioceris asparagi* and *Crioceris duodecempunctata* (12-spotted), may be controlled by close cutting during the harvest season. Rotenone may be used later if necessary. There is danger of underestimating the seriousness of the damage as the insects chafe the foliage surface.

The garden centipede, *Scutigerella immaculata,* is a serious enemy in California. Control is by flooding for three or four weeks during midwinter.

Cutworms are sometimes troublesome and may be controlled with poison bait or DDT.

Harvesting and Marketing

Asparagus begins to grow as soon as warm weather comes in the spring, beginning late in March in South Carolina, and from mid-April to May 10 in most of the north. The California Delta season begins in late February or early March.

Normal cutting season in most regions is about 8 weeks, but 10 weeks is usual in California. In some areas, where the growing season is long, asparagus may be cut the second season after planting, but in most regions this is not profitable as shown by Haber[6] and Lewis.[7] When spears become slender and woody, cutting should be stopped to avoid excessive depletion of roots and the reduction of yields of later years.

Cutting is usually done with a long knife with a fishtail blade. It should be sunk in the soil parallel to the stalk, then tilted for the cut. Otherwise there is danger of damage to younger shoots and buds. An unseen shoot, nicked under the soil, may never come up, or it may come up curved like a shepherd's crook. Insect or other injury may have the same effect.

For processing some asparagus is "snapped" rather than cut, reducing cost and yielding a higher percentage of tender stalk.

Ordinarily a bed is cut every other day, every day in warm weather, but in cool weather it may go uncut three or even four days. If spears become too tall they are slender, woody, and inclined to feather or branch.

Containers. In small-scale operations and some larger ones, cutters carry baskets or boxes to receive the shoots, laid like cordwood, tips one way. Where there are several cutters and each on his own row, the first may put a handful into a basket or box and pass it over one row for the next cutter, thus saving a good deal of carrying. Western growers use a cart that straddles the rows, the driver picking up the handfuls left by the cutters and stacking them in the body.

Bunching. Many kinds of boxes and forms are used for bunching and trimming asparagus, usually to a length of 7 to 9 inches. A box of proper length with one end open serves as a good guide for cutting off the butts. Spears may be made

up by hand into small bunches of ½ or 1 pound, using rubber bands. Shipped asparagus, and some for near-by market, is commonly put up in 2-pound or 2½-pound bunches tied with cotton braid, tape, or raffia. A parchment paper wrap is sometimes used. Some asparagus is shipped loose in the crate, to be weighed up at the retail store.

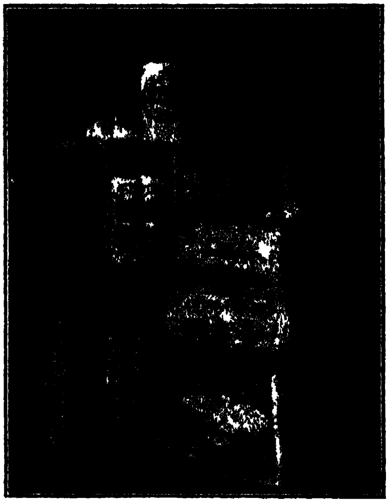

FIG. 28.3. Two packs of good asparagus. Growers have to decide whether labeling, wrapping, and "dress-up" pay or not. Practices should be judged on value in conserving quality and on sales results.

The usual asparagus box is slant-sided, approximately 10½ inches deep, 9½ inches wide at the top, 10½ at the bottom, and 17½ inches long, with some regional variations. Bunches are set upright in it. Wet sphagnum moss is sometimes put in the bottom to supply moisture. Long-distance shipments are usually made under refrigeration.

Bisson and others[8] have shown that asparagus may increase in length, dry matter, sugars, and fiber after harvest. If water is available at the base, the stalks gain in actual weight. Since asparagus shoots represent very active plant tissues, precooling and refrigeration are especially useful.

CONCERNING ASPARAGUS

Food use

Asparagus cannot be rated very highly for nutritive value although it ranks well in thiamin (B_1), riboflavin (B_2), and ascorbic acid (C) but, coming early in the spring, it is a high favorite as a table vegetable for delicacy and appetizing flavor. It is quickly cooked and requires no sauce or accessory, though it is often served on toast, either with butter or creamed. It may also be cooked and served cold as a salad with mayonnaise or other dressing.

Botany

Asparagus, *Asparagus officinalis,* belongs to the family Liliaceae, along with the lily, tulip, hyacinth, gladiolus, and smilax. Two members of the genus, *A. sprengeri* and *A. plumosus,* are much used for decorative greenery.

The crown is a mass of branching, rather woody rhizomes or rootstocks, with buds at the tips which give rise to the edible shoots. Rhizome branches die off and others grow, usually a little above the old ones; as a result, the crowns are nearer to the surface in an old bed.

The root system consists of a great number of tubular roots about ⅛ to ¼ inch in diameter which serve as storage organs and which bear fibrous feeding roots as branches. They are sometimes 9 or 10 feet long (see Weaver and Bruner, ref. 4 of Chapter 7). A five- or six-year-old plant can easily have a mile of tubular root, which is highly significant when one recalls that every shoot that appears during eight weeks is ruthlessly cut and another takes its place with an average seasonal total yield of a pound per plant in a good bed. Hanna[3] has had single plants yielding up to 10 pounds and more in a season.

Stems arise from buds on the rhizomes, ranging to diameters as large as an inch, but mostly from ¼ to ¾ inch. They become woody with age, owing to lignification of pericycle tissue.

Leaves are insignificant bracts, most of the photosynthesis taking place in stems and in tiny leafless branches called *cladodes.*

Flowers. Asparagus is dioecious; that is, male and female flowers are on separate plants, although hermaphroditic plants occur. The flowers, fruits, and seeds are of characteristic lily pattern, on the plan of three.

Seeds occur in a berry of three carpels, usually two seeds per carpel. A pound contains 20,000 to 25,000 seeds.

Yield

The cannery yield in California is a little over a ton per acre, and the 10-year average for market is about 90 crates per acre of 30 pounds each. Washington reports yields twice as great as California. A good planting may yield 2 tons per acre over a period of years.

History

Asparagus is found wild in southeastern and southern Europe, and it has become established as an escape in many parts of the world. It persists thus in California and in New Jersey. The Romans of 200 B.C. esteemed asparagus as a great delicacy and its culture is frequently described in Latin literature. Its history from then to modern times is obscure.

RHUBARB

Rhubarb, like asparagus, is perennial. It is prized for the refreshing acidity of its leaf stalks or petioles which grow up

FIG. 284 Rhubarb roots.

very early in the spring, giving us one of our earliest fresh green things from the garden. It is easily grown and perfectly hardy. A short row, say 6 or 12 hills, will supply a family for sauce and pie. It is easily canned, and its cooked juice with a bit of lemon and sugar makes a most refreshing beverage.

In the home garden, rhubarb requires no more than ordinary good care and fertilizing. It is propagated by dividing up the fleshy roots which are surmounted by strong buds or crowns. Seed ordinarily does not "come true," presumably because nobody has taken the trouble to develop pure strains, with the exception of some of our newer sorts.

Rhubarb is widely grown near city markets, but prices usually fall to unprofitable levels very quickly. Rhubarb is harvested a year after setting, and a planting lasts almost indefinitely al-

though plants should be taken up, divided, and replanted when petioles become small and spindling from overcrowding.

Varieties. **Victoria,** with large leaf stalks and vigorous growth, is the commonest variety. The color is not as high as in some newer varieties, such as **MacDonald** and **Ruby,** which, however, are less vigorous in growth. **Linnaeus** or **Strawberry** is an old variety of good color but with rather slender petioles. **Valentine** is a new variety offering both vigor of growth and fine color and quality.

Planting. Rhubarb is planted in rows 3 or 4 feet apart, about 2 feet apart in the row, with roots vertical and the crown just under the surface.

Rhubarb is harvested by pulling the leaves. Ordinarily most of the blade is broken off. It is sold in bunches, the size being governed by market custom.

Forcing. Rhubarb roots are dug in the fall and allowed to freeze. Then they may be placed in cold frame, hotbed, cellar, common storage, or some other suitable place, crown up, as closely as they can be packed, with earth between the roots. At a temperature of 60° or 65° F. and with proper moisture, leaf stalks of fine color and small blade grow up and are ready for home use or market. Light is not necessary since the products of last year's photosynthesis are stored in the fleshy roots. Near Detroit a great rhubarb-forcing industry has grown up, most growers using crude buildings and hot-water heat. The product is packed in 5-pound cartons, 10 or 12 of which fill a large paperboard shipping box. Roots after forcing may be divided and reset.

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